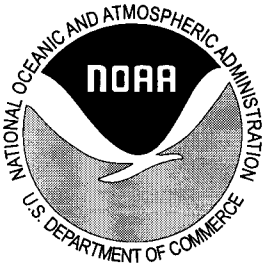

Administrative Report H-99-05

1999 PROGRAM REVIEW HONOLULU LABORATORY

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Preface

The Honolulu Laboratory was recently honored by receiving Vice President Al Gore's national **Silver Hammer** award. This special, prestigious award is granted in recognition of significant efforts at reinventing Federal Government. The Laboratory received the award for partnering with private industry, federal, and state agencies, civil organizations, and academia in the cleanup of derelict fishing gear and other marine debris from coral reefs in the Northwest Hawaiian Islands. Leadership in the reef clean-up effort was by the Laboratory Hawaiian Monk Seal Program. The award was presented by U.S. Senator Daniel Inouye, senior member of the Hawaii Congressional delegation (Fig. 1).

Figure 1. U.S. Senator Daniel Inouye presents the Vice President's Silver Hammer award to Honolulu Laboratory Director Dr. R. Michael Laurs and representatives from participating private industry, federal, and state agencies, civil organizations, and academia.

In addition to scientific contributions in support of fisheries management and the recovery of protected species in the central and western Pacific, Honolulu Laboratory staff are noted for their generosity and support of charities. In 1999 the Laboratory received a Gold Award from the Combined Federal Campaign in recognition of its high level of commitment to the community.

The Honolulu Laboratory staff are also consistently honored for their accomplishments. This year, Jeffrey Polovina, Chief of the Ecosystem and Environment Investigation, was named a Fulbright Scholar for his work on the assessment of spiny lobster in the Galapagos.

Hard work, dedication, and a giving nature characterize the Honolulu Laboratory and set it apart from other facilities. We are proud to share our accomplishments for 1999 in this publication.

Contents

THE NMFS SOUTHWEST FISHERIES SCIENCE CENTER

HONOLULU LABORATORY

The NMFS Honolulu Laboratory celebrated its Golden Anniversary in 1998. During the past 50 years the Laboratory has had an illustrious history of performing fisheries exploration and development, conducting fisheries research, and providing scientific information and expertise in support of fisheries management and protected species recovery in the central and western Pacific. Several events were held to mark this special occasion:

> Special session at the annual Tuna Conference featuring 50 years of tuna research at the Honolulu Laboratory.
>
> Commemorative session at the Eastern Pacific Oceanic Conference (EPOC) on the contributions made by the Laboratory to understanding the oceanography of the Pacific.
>
> Press conference and open house highlighting the 50th anniversary of the Laboratory, announcing the new Laboratory construction project, and awarding the Laboratory the vice-presidential Silver Hammer Award by Senator Daniel Inouye, leader of the Hawaii Congressional delegation.

Mission of the Honolulu Laboratory

The mission of the Honolulu Laboratory is linked to the NOAA Strategic Plan to Build Sustainable Fisheries, Recover Protected Species, and Maintain Healthy Living Marine Resource Habitats and to the Department of State priorities concerning international management in the Pacific highly migratory species (HMS).

Goals

Goals of the Honolulu Laboratory are to provide scientific information and advice for the following:

- Management of domestic fisheries in the U.S. Exclusive Economic Zones (EEZ) in the central and western Pacific.
- Support of U.S. interests in the international management of Pacific HMS.
- Recovery and management of the highly endangered Hawaiian monk seal and protected Pacific sea turtles and assessment and mitigation of seabird mortality resulting from fisheries interactions.

Objectives of the Fisheries Research Program

The objectives of the Honolulu Laboratory's fisheries research program include the following:

- Biological and ecological research in support of four fishery management plans (FMPs)

Pelagic Fisheries of the Western Pacific FMP--This FMP regulates fishing for pelagic species including tunas, swordfish, marlins, sharks, mahimahi, opah (moonfish), ono (wahoo), and other pelagic species within the EEZs of U.S.-affiliated islands in the western Pacific. This includes the important commercial domestic longline, troll, handline, and pole-and-line fisheries operating out of Hawaii, and albacore longline fishery operating out of American Samoa

Crustacean Fisheries FMP of the Western Pacific--The Northwestern Hawaiian Islands (NWHI) trap fishery for spiny and slipper lobsters is managed under this FMP.

Bottomfish and Seamount Groundfish Fisheries FMP of the Western Pacific--Snapper, grouper, and jack species in American Samoa, Guam, Hawaii, and the Commonwealth of the Northern Mariana Islands (CNMI) are managed under this FMP. In addition, this FMP includes provisions for management of the Hancock Seamount armorhead resource.

Precious Coral FMP of the Western Pacific FMP--Precious corals in this fishery include Pink Coral (*Corallium secundum*, *C. regale*, and *C. Laauense*), Gold Coral (*Gerardia spp.*, *Narella spp.* and *Calyptrophora spp.*), Bamboo coral (*Lepidisis olapa* and *Acanella spp.*), and Black Coral (*Antipathes dichotoma*, *A. grandis, A. ulex*).

- Biological and ecological research in support of international management of Pacific tuna and Tuna-like species

Leadership in International Organizations--Provide leadership in international organizations and actions in preparation for management of Pacific HMS; e.g., the Interim Scientific Committee for Tuna and Tuna-like Species in the North Pacific (ISC), Multi High-Level Conference (MHLC), etc.

Conduct International Cooperative Research--Conduct cooperative research with several Pacific rim countries on Pacific HMS and related issues.

- Economic research on fisheries policy and management alternatives.

- Fisheries oceanography research related to marine ecosystems.

- Collection of fisheries statistics to monitor the status of western Pacific fisheries.

Objectives of the Protected Species Research and Recovery Program

The Honolulu Laboratory's research efforts supporting the NOAA Strategic Plan to Recover Protected Species include the **Hawaiian Monk Seal Program, Pacific Sea Turtle Program**, and research concerning **Fisheries Interactions with Seabirds**.

Objectives of the **Hawaiian Monk Seal Recovery Program are:**

- Determine population status at the main monk seal breeding sites.
- Conduct rehabilitation and relocation operations.
- Identify and mitigate problems impeding population recovery; e.g. mobbing and marine debris.
- Recommend, coordinate, and cooperate in intra- and inter-agency recovery efforts.

Objectives of the **Pacific Sea Turtle Recovery Program are:**

- Study biology, ecology, and natural history of Pacific sea turtles, with emphasis on the Hawaiian green sea turtle.
- Conduct research in support of the NMFS Biological Opinion concerning interactions between the Hawaii longline fishery and sea turtles.
- Develop models for assessing status of Pacific sea turtle populations.
- Investigate the fibropapilloma disease epidemic in green and olive ridley sea turtles.
- Provide technical assistance and training in the Pacific region to promote collections of reliable data on sea turtles.

Objectives of the research related to **Fisheries Interactions with Seabirds are:**

- Investigate seabird mortality caused by longline fishing operations.
- Estimate seabird mortality resulting from longline fishery interactions.
- Determine mitigation methods for reducing seabird mortality resulting from longline fishery interactions.

Geographic Area of Responsibility

The geographic area of responsibility of the Honolulu Laboratory is the largest of all U.S. fisheries laboratories. The vast area is bounded by the entire Hawaiian Archipelago in the north, American Samoa and U.S. possessions in the south, and the Marianas Archipelago in the west (Fig. 1). The area of these EEZs is more than 1.7 million square nautical miles, which is equal to the total EEZ of the entire U.S. mainland (including Alaska).

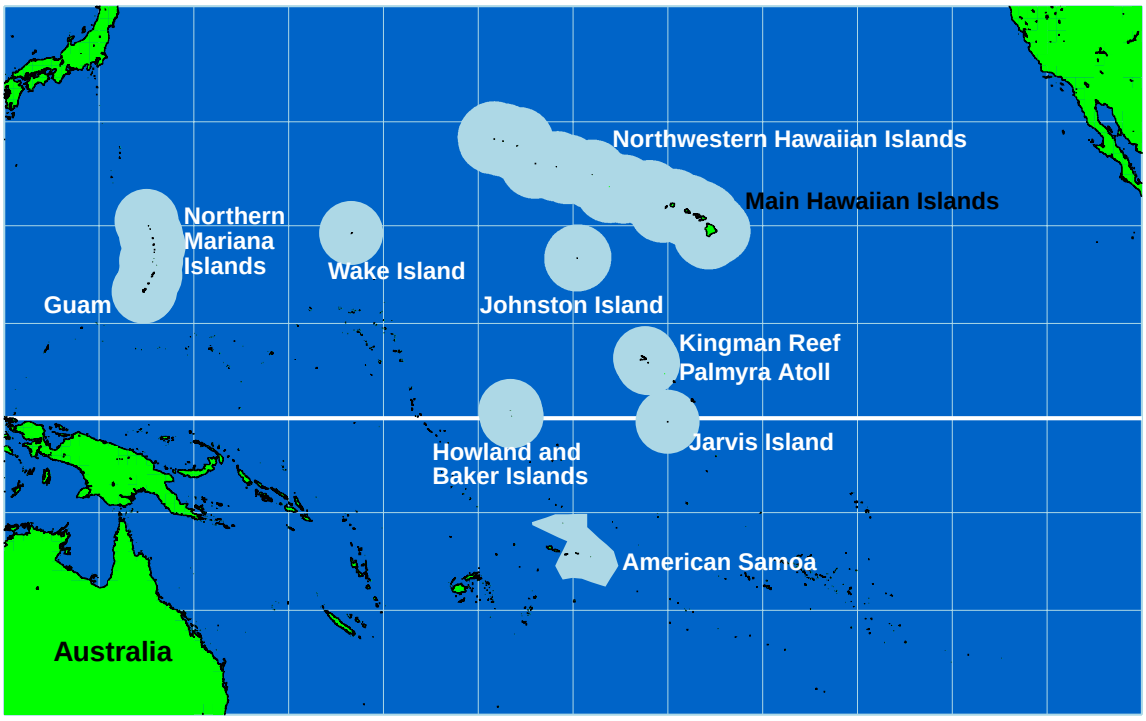


Figure 1. Honolulu Laboratory area of responsibility shown in light blue.

HONOLULU LABORATORY BUDGET, STAFFING, AND ORGANIZATION

Honolulu Laboratory FY 1999 Budget

The FY 1999 budget for the Honolulu Laboratory is nearly $7.8 million. NMFS base funds allocated to the Laboratory by the SWFSC cover about $3.8 million of this budget. The balance comes from several sources including NMFS add-on funds from F/PR and SWR amounting to about $1.03 million, from Congressional PPAs totaling about $1.31 million, other PPAs $1.41 million, and other funding about $0.22 million. A summary of the budget by funding source and selected programs is provided in Table 1.

Table 1. Honolulu Laboratory FY 1999 Budget

Funding Source	Amount ($1,000)
NMFS base	$3,799.1
NMFS add-on	
Monk seal	103.9
Sea turtle	299.2
WPacFIN	339.9
EFH	152.0
HMS - Stock Assessment	100.0
Shark Assessment	34.0
PPA Congressional	
Monk seal	648.8
Sea turtle	258.4
Swordfish	400.0
PPA Other	
Monk seal	800.0
Sea turtle	282.0
Fisheries Info Technology	146.3
WPacFIN - Base	189.5
Other Funding	
ESDIM - Data Rescue	98.0
CoastWatch (NESDIS)	121.0
TOTAL	$7,772.1

Honolulu Laboratory NOAA and UH/JIMAR Staff

The staff at the Honolulu Laboratory includes 55 NOAA/NMFS employees, 2 NOAA Corps officers, and 65 NOAA/UH Joint Institute for Marine and Atmospheric Research (JIMAR) employees. Most of the UH/JIMAR staff members are funded by grants awarded by the Laboratory to the UH/JIMAR. Some of the UH/JIMAR staff members are supported from research proposals awarded competitively to Laboratory scientists by the JIMAR Pelagic Fisheries Research Program (PFRP) (see section on Honolulu Laboratory Relationships with the University of Hawaii for further discussion). Thirty-seven UH/JIMAR staff members are full-time, 17 are part-time or seasonal hires, and 11 are student assistants. The number of staff members by category appears in Table 2.

Table 2. Honolulu Laboratory NOAA and UH/JIMAR Staff

Organization	Number
NOAA	
NMFS	55
NOAA Corps	2
Total NOAA	57
UH/RCUH-JIMAR Staff	
Administration Staff	1
Fishery Oceanography	35
WestPacFin	11
CoastWatch	1
MARDAP	13
Pelagic Fishery Research Program	3
Full-time	37
Part-time	1
Seasonal hires	16
Student Assistant	11
Total non-NOAA	65
TOTAL	122

Honolulu Laboratory Organization

The Laboratory is organized into the Director's Office, Administrative Services, and Scientific Information and Technical Services, which includes the NOAA CoastWatch Site, and five research investigations:

Fish Biology and Ecology Investigation

Life History Program

Fish Ecology Program

Ecosystem and Environment Investigation

Fisheries Oceanography Program

Ecosystem and Habitat Program

Stock Assessment Investigation

Fishery Monitoring and Economics Program

Fishery Data Management Program

Western Pacific Fishery Information Network Program

Protected Species Investigation

Marine Mammal Research Program

Marine Turtle

An organization chart for the Laboratory is given in Figure 2; a listing of staff by investigation or program is given in Table 3; and a photograph of Honolulu Laboratory staff appears in Figure 3.

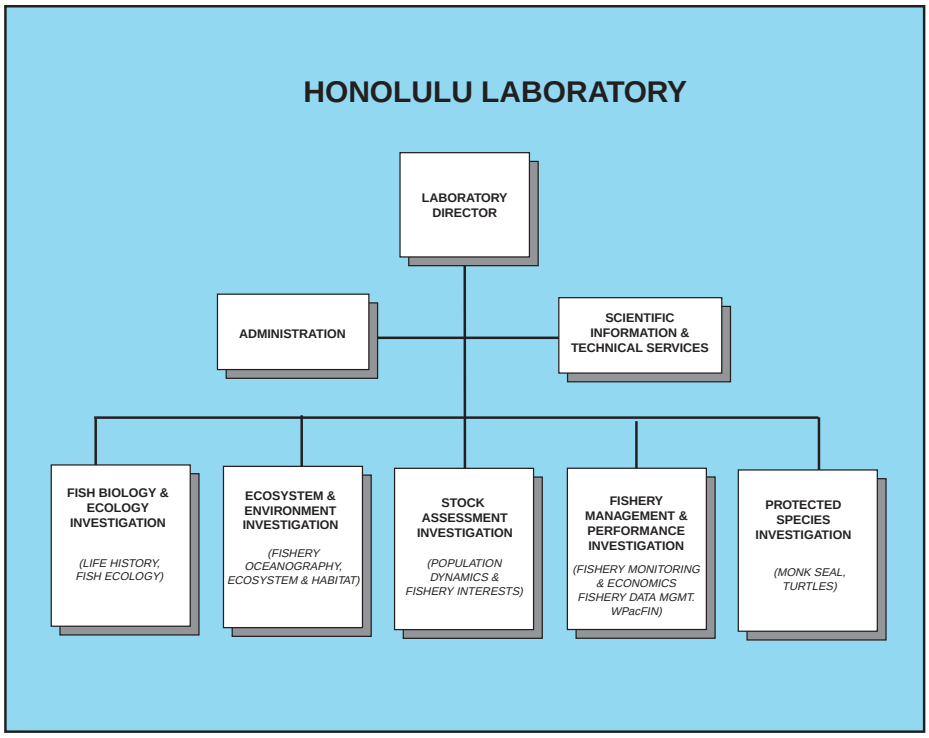


Figure 2. Schematic showing organization of Honolulu Laboratory.

Program Management and Research Teams

Program management at the Honolulu Laboratory follows a hybrid form of matrix management, with extensive interactions across five research investigations, which are organized on a functional basis.

Multidisciplinary Teams

Honolulu Laboratory's Multidisciplinary Teams are used to plan, conduct, and coordinate research projects as well as to ensure communications among all the parties involved. The Teams are made up of individuals from several or all of the Laboratory research investigations and service support groups. These teams are described below.

Investigation Chiefs Team--This Team consists of the Laboratory Director, Chiefs of the five research investigations, the Administrative Officer, the head of Scientific Information and Technical Services, the Science Program Coordinator and the Director's program support assistant. The purpose of this Team is to serve as a board of directors for the Laboratory, to develop policy, to promote open communication among the operating units of the Laboratory, and to coordinate actions among the various groups as needed.

Table 3. Personnel, Honolulu Laboratory

DIRECTOR'S OFFICE
R. M. Laurs, Director, Supvy. Oceanographer
W. Goo, Program Support Assistant
R. Brainard, NOAA Corps

ADMINISTRATION
S. Kamei, Administrative Officer
F. Fiust, Editorial Assistant
J. Kendig, Writer-Editor
J. Tamanaha, Purchasing Agent
B. Oshiro, Admin. Support Assistant
S. Wong, Budget Assistant
H. Gerboc, General Maintenance Assistant*
D. Sugimoto, Fiscal & Administrative Support Specialist*
L. Gerboc, Student (P/T)*
S. Yamamoto, Student (P/T)*

SCIENTIFIC INFORMATION & TECHNICAL SERVICES
D. Tieman, Comp. Sys. Analy.
D. Foley, CoastWatch Coordinator*
E. Howell, Research Associate*
M. Parke, Computer Specialist*
S. Abbott-Stout, Librarian
D. Yamaguchi, Scientific Illustrator
W. Higuchi, Computer Specialist
J. Pappas, Computer Specialist
R. Price, Computer Specialist
R. Uyeda, Computer Specialist
R. Yoshimoto, Computer Assistant
R. Skillman, Fishery Biologist
J. Dane, Computer Specialist*

FISH BIOLOGY & ECOLOGY INVESTIGATION
C. Boggs, Supvy. Fishery Biologist
R. Brill, Fishery Biologist
R. Chang, Fishery Biologist
E. DeMartini, Fishery Biologist
R. Humphreys, Fishery Biologist
T. Kazama, Fishery Biologist
R. Moffitt, Fishery Biologist
B. Mundy, Fishery Biologist
R. Nishimoto, Fishery Biologist
J. Sampaga, Bio. Sci. Tech. (Micro)
P. Shiota, Fishery Biologist
J. Uchiyama, Fishery Biologist
H. Williams, Bio. Sci. Tech. (Micro)
D. Curran, Fishery Biologist*
M. Musyl, Fishery Oceanographer*

ECOSYSTEM & ENVIRONMENT INVESTIGATION
J. Polovina, Math. Stat.
D. Kobayashi, Fishery Biologist
F. Parrish, Fishery Biologist
M. Seki, Fishery Biologist
S. Murakami, Oceanographic Technician*

STOCK ASSESSMENT INVESTIGATION
J. Wetherall, Fishery Biologist
G. DiNardo, Fishery Biologist
P. Kleiber, Fishery Biologist
M. Labelle, Senior Researcher*
G. Epstein, Computer Specialist

FISHERY MANAGEMENT & PERFORMANCE INVESTIGATION
S. Pooley, Supvy. Industry Economist
F. Cabacungan, Computer Specialist
F. Dowdell, Computer Specialist
D. Hamm, Supvy. Comp. Spec.
R. Ito, Fishery Biologist
K. Kawamoto, Fishery Biologist
B. Kikkawa, Fishery Biologist
B. Miyamoto, Computer Specialist
M. Quach, Computer Specialist
D. Tagami, Operations Research Analyst
L. Tsukano, Computer Assistant
A. Carlos, Student (P/T)*
N. Chan, Data Entry/Processing Clerk*
D. Gonzales, Computer Specialist*
C. Graham, Computer Specialist*
E. Glazier, Research Associate*
W. Walsh, Asst. Researcher*
L. Kim, Student (P/T)*
W. Machado, Fishery Assistant*
M. Pan, Graduate Research Associate*
J. Pitko, Computer Specialist*
P. Tao, Computer Specialist*
C. Tokita, Data Processing Clerk*
C. Althen, Computer Specialist*
K. Pataradool, Computer Specialist*
V. Abellera, Computer Specialist*

PROTECTED SPECIES INVESTIGATION
G. Antonelis, Supvy. Wildlife Biologist
J. Baker, Marine Biologist
G. Balazs, Zoologist
B. Becker, Wildlife Biologist
R. Dollar, Bio. Sci. Tech
J. Henderson, Fishery Biologist
T. Johanos-Kam, Wildlife Biologist
C. Sramek, NOAA Corps
M. Donohue, Mairne Debris Coordinator*
R. Boland, Biological Technician*
M. Craig, Research Associate*
S. Eames, Data Entry Clerk*
D. Ellis, Research Associate*
L. Kashinksy, Vet. Medical Technician*
S. Murakawa, Research Associate*
B. Ryon, Biological Technician*
M. Shaw, Biological Research Technician*
H. Swensen, Computer Specialist*
C. Yoshinaga, Logistic Coordinator*
C. Cornish, Biological Research Specialist*

16 seasonal hires and 11 student assistants not included.

***JIMAR**

Figure 3. Honolulu Laboratory staff photograph

Swordfish Research Team--The goal of the Swordfish Research Team is to provide an operational multidisciplinary framework for identifying, prioritizing, conducting, and coordinating swordfish research. A comprehensive research plan encompassing fishery monitoring, stock assessment, and biological and fishery oceanography research has been developed by the team, which is comprised of scientists and managers from the Honolulu Laboratory, the Council, and UH/JIMAR.

Oracle Database Development Team--The Oracle Database Development Team was established to ensure the coordinated conversion of Hawaiian monk seal, Pacific sea turtle, and pelagic fisheries data, as well as other fisheries and related data within the Honolulu Laboratory Oracle database system. The team was expanded to include web site management and GIS development.

Lobster Research Team--The Lobster Research Team was formed in response to the need to develop new methods for determining the annual harvest guideline (quota) for the NWHI lobster fishery for the efforts related to Amendment 9, and for research planning. The Team consists of scientists from the Honolulu Laboratory, UH/JIMAR, NMFS/SWR, and the Council. Presently, the Team is primarily responsible for appraising the new harvest guideline procedures, planning lobster research, coordinating research activities, and advising the Laboratory Director on lobster research needs.

Scientific Information and Technical Support Services

The objectives of this group are to provide scientific and technical support for the Honolulu Laboratory and the SWR Pacific Islands Area Office (PIAO), including the following:

- Computer hardware and software systems.
- Communications systems; e.g., Laboratory LAN, agency WAN, and data communication networks linked with the University of Hawaii and the National Weather Service.
- Computer and communication systems security.
- High technology applications for data management and distribution, including Oracle System, Web Site, and Geographic Information System (GIS).
- Library and graphics services.
- NOAA CoastWatch operations

Director's Office and Administration

The primary objectives of the Director's Office are to provide overall scientific leadership and research direction, program management, and operational policy. In addition, the office is responsible for liaison with other NMFS and NOAA offices, the Council, the University of Hawaii, the State of Hawaii, and other agencies and organizations.

The Administration group provides comprehensive administrative services for procurement, budget planning and implementation, fiscal monitoring, personnel management, travel, and facilities management. The editorial section of Administration provides scientific editorial services for the Honolulu Laboratory.

Publications and Scientific Meeting Presentations

Sixty-one manuscripts have been approved, submitted for publication, in press, or published by Laboratory scientists during FY 1999. A listing of publications is found in Appendix 1. The numbers of publications by category are as follows:

Fishery biology/ecology - 10

Fisheries and fishery interactions - 18

Physical and biological oceanography - 2

Hawaiian monk seals - 9

Sea turtles - 19

Fisheries economics and social science - 3

The Laboratory staff also prepared 56 administrative reports, abstracts, and workshop proceedings. In addition, Laboratory scientists gave 88 presentations at over 50 scientific meetings as well as over 100 presentations to the Council Plan Teams, Science and Technical Committees, and full Council meetings.

Honolulu Laboratory Relationship with Council and SWR/PIAO

The Honolulu Laboratory shares a close working relationship with the NMFS SWR Pacific Islands Area Office (PIAO) and the Council: The Council prepares and recommends fishery management actions to NMFS; the PIAO prepares fishery management regulations and is responsible for carrying out fishery management actions; and the Honolulu Laboratory provides scientific advice and input for domestic fishery actions to both the Council and the PIAO.

Honolulu Laboratory Relationships with the University of Hawaii

The Honolulu Laboratory is located on the University of Hawaii (UH) Manoa campus. It has extensive relations with the University, resulting in significant mutual benefits. Several of the Laboratory's senior investigators hold UH adjunct professorships or senior research fellow positions, lecture UH courses in marine science and related topics, and serve as scientific advisers to undergraduate and graduate students. UH students serve as a source of talented and motivated temporary help for the Laboratory. The Laboratory computer Internet access and other computer communications are handled through the UH Computer Center, and the NOAA ship assigned to the Laboratory, *Townsend Cromwell* is berthed and receives port support from the UH. The UH also provides some environmental compliance maintenance for the Laboratory as well as after-hours security. Most direct associations between the Laboratory and the UH are through the NOAA/UH JIMAR.

Joint Institute for Marine and Atmospheric Research (UH/JIMAR)

The Laboratory has many interactions with the UH/JIMAR including the opportunity for Laboratory scientists to compete for pelagic fisheries research funding that is awarded competitively by the JIMAR/PFRP. The JIMAR/PFRP administers funding received from Congressional funding. Laboratory scientists have successfully competed for JIMAR pelagic fisheries research funds and over the past 5 years have served as Principal or Co-Principal Investigators on 11 projects totaling more than $2 million. In addition, substantial complementary, collaborative, and cooperative research on pelagic fisheries is conducted by Laboratory and UH/JIMAR scientists.

The Laboratory utilizes the NOAA/UH Joint Institute program by awarding grants to JIMAR for research in support of the mission of the Laboratory. In FY 1999 the Laboratory awarded grants totaling about $1.41million to JIMAR to support research and operations at the Laboratory. A summary of the funding by projects is provided in Table 4. The Laboratory also participates in the JIMAR visiting scientist program.

Table 4. Honolulu Laboratory Funds Awarded to UH/JIMAR in FY 1999.

($1,000)

Programs	Amount	Total
Fishery Oceanography		$ 843.3
Pacific Swordfish Research	238.7	
Recovery of Hawaiian Monk Seal	481.0	
Pacific Sea Turtle Biology and Ecology	123.6	
Western Pacific Fishery Information Network Project	259.9	259.9
Marine Resource Dynamics and Assessment Program (MARDAP)		263.0
Sea Turtle Assessment and Monitoring	27.1	
Research Support	113.4	
Geographic Information System for Fisheries Database System	59.5	
Data Rescue	63.0	
NOAA CoastWatch Operations	75.0	75.0
TOTAL		$1,441.2

NOAA CoastWatch

The NOAA CoastWatch site, which is funded by NOAA/NESDIS, is located at the Honolulu Laboratory. The site has direct readout of NOAA satellites (shared with NOAA/NWS) and satellite image processing systems. Satellite-derived ocean data products are produced at the CoastWatch site for distribution to federal, state, and local agency and university researchers involved in marine science, policy, and management. Over the past year, there has been a significant expansion in the amount of satellite information available from the CoastWatch Site, including new sea surface temperature, ocean circulation, ocean wind, and ocean color products. CoastWatch data products are increasing in use in Honolulu Laboratory fisheries and protected species research. See Fishery Oceanography and Essential Fish Habitat sections of this report for information about the expanded use of CoastWatch satellite-derived ocean data products in Laboratory research.

IMPORTANCE OF CENTRAL AND WESTERN-PACIFIC FISHERIES

Fisheries under U.S. jurisdiction in the central and western Pacific are healthy and viable, as well as economically and socially important and valuable. The condition of these fisheries appears to be the best of all regions in the U.S. for which NMFS is responsible. However, great care and continued attention must be taken to preserve this healthy state in the widest geographical jurisdiction in the United States.

Analyses of pelagic fisheries in the central Pacific show no signs of overfishing, although some stocks may be near their sustainable yields. The Hawaii swordfish fishery has shown a complete recovery in CPUE (catch per 1,000 hooks) following a steep decline in 1994. Although swordfish landings have declined since 1993, this is primarily because a number of swordfish longliners left Hawaii in 1993 and 1994 and other swordfish boats shifted their fishing effort to the more lucrative bigeye tuna.

Longline catch of tunas, billfish, and associated pelagics grew substantially in Hawaii from the mid-1980s through 1998 (record landings in weight but not in value), while the small-scale longline fishery operating out of American Samoa has grown dramatically.

The lobster and bottomfish (snappers, groupers, and jacks) fisheries in the Northwestern Hawaiian Islands (NWHI) are both in good condition, following proactive measures by the Council and NMFS. The lobster fishery is now a limited entry, restricted season, quota-based fishery while the bottomfish fishery is also subject to limited entry. The Hancock Seamount stocks of deep-sea groundfish (armorhead) have not recovered following overfishing by foreign fishing vessels prior to the implementation of the Magnuson-Stevens Act in 1976. This fishery remains closed by Council action and a long-term moratorium has been proposed. The Hawaii precious corals fishery–which has been inactive for years–has recently been surveyed by a commercial vessel using ROV (remote operated vehicle) technology, and it too appears healthy. Fishing on these resources is expected to resume in the near future.

Several nearshore fisheries in the main Hawaiian Islands (MHI) and Guam have shown significant stress (e.g., MHI bottomfish). The State of Hawaii has implemented a series of closed areas for bottomfish in the main islands, and additional biological and genetic research is being carried out to resolve the stock structure of these populations (relative to the NWHI).

The status of coral reefs in Hawaii and other areas of the central Pacific has recently been highlighted, with the Laboratory taking a number of steps to reduce the impact of marine debris (primarily lost fishing nets from the North Pacific) on these reefs. An ambitious research and mitigation program has been planned for the next 5 years.

Three western Pacific ports (Pago Pago, American Samoa; Agana, Guam; and Honolulu, Hawaii) rank in the top 10 of the most valuable fishing ports in the United States when distant-water landings are included.[1] The ex-vessel value of landings in these ports is approximately $350 million

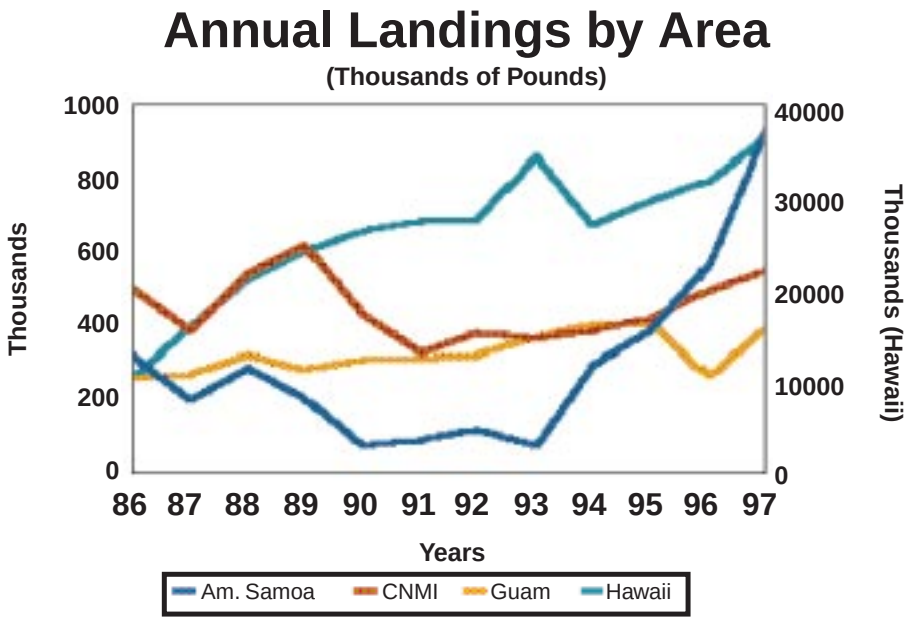
[1]Landings by domestic and foreign purse seine vessels in American Samoa and Guam are not reported in published statistics because of confidentiality restrictions. These estimates are based on reports from the governments of these island areas.

(Table 1). U.S. canneries are the primary private sector employer in American Samoa and make a substantial contribution to operations in the Port of Guam. Local fisheries have grown substantially in American Samoa, Guam, and the Northern Marianas over the past 10 years (Fig. 1), fisheries also have an important economic impact in Hawaii and are perhaps even more important socially and culturally. Growth in Hawaii's fisheries was dramatic in the 1980s and 1990s, leveling off in 1998 (Figs. 2 and 3).

Table 1. The ten most valuable U.S. fishing ports (including distant-water landings for the central and western Pacific), 1997.

Ex-vessel value – $ millions

Rank	Port	Landings value $ million ex-vessel
1	**Pago Pago (1996 value)**	**$212**
2	Dutch Harbor - Unalaska	123
3	New Bedford	103
4	**Agana, Guam (1996 value)**	**94**
5	Kodiak	89
6	Empire-Venice, Louisiana	58
7	Key West	55
8	**Honolulu**	**54**
9	Point Judith, Rhode Island	48
10	Brownsville, Texas	46



Based on estimated total commercial landings

Figure 1. Annual commercial landings 1986-97.

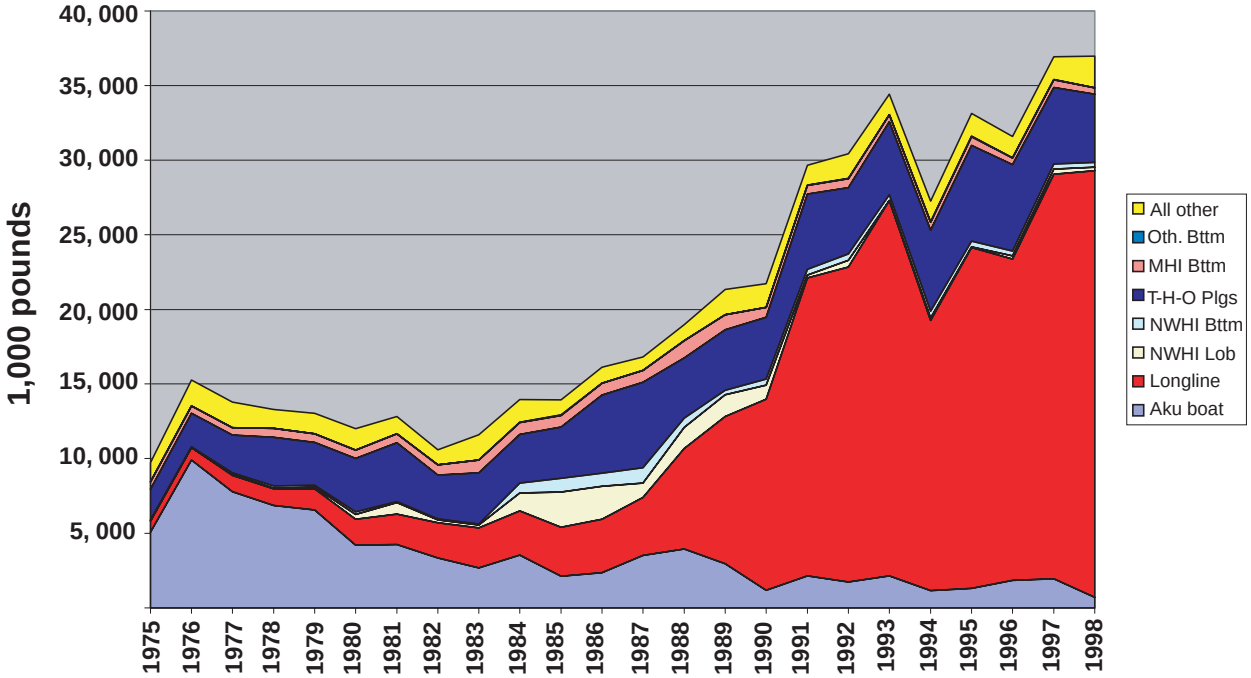


Figure 2: Hawaii commercial landings, 1975-present.

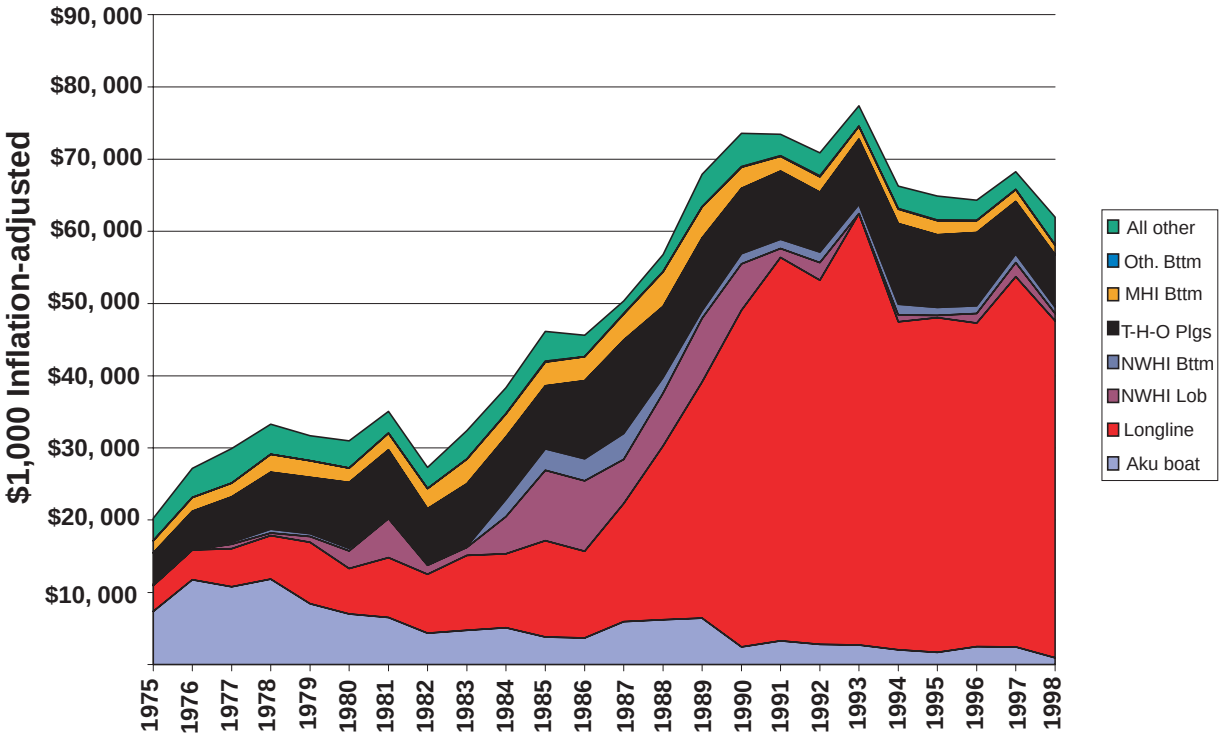


Figure 3. Hawaii commercial fishery revenue (ex-vessel, inflation-adjusted to current year), 1975-present.

FISHERY MONITORING AND STATISTICS

Background

Fishery monitoring is a critical step in the mission of the Honolulu Laboratory. These operations involve two programs at the Honolulu Laboratory: fisheries information obtained from Federal logbooks and shoreside monitoring, and the Western Pacific Fishery Information Network (WPacFIN), which compiles island fisheries agency data and provides these agencies with technical assistance. This information is used for domestic fisheries management in Hawaii, as well as for basic biological and habitat research and fisheries statistics and data management assistance to American Samoa, Guam, Hawaii, and the Northern Marianas through WPacFIN cooperative agreement. Information is also compiled and distributed for international management of highly migratory species (HMS) through various international conventions and bodies (e.g., the ISC and the Secretariate of the Pacific Community's Standing Committee on Tunas and Billfish). Increasingly Laboratory staff are involved in the information systems utilized by the NMFS observer programs operated out of Honolulu through the SWR/PIAO. Domestic fishery monitoring involves the following activities:

- Collecting and processing fishery-dependent information (i.e., logbooks).
- Conducting economics research on Federally managed fisheries.
- Issuing quarterly and annual reports on Federally managed fisheries (including longline, bottomfish, and lobsters).
- Developing computer-based data quality control and summarization programs.

Fishery Monitoring Goals and Approach

The Honolulu Laboratory's fishery monitoring goals can be summarized as follows:

- Provide fisheries-dependent data for biological and economic research, including information for ecosystem management, marine habitats, and fisheries interactions with protected species (e.g., marine turtles and sea birds).
- Provide reports on the status of landings and fishing activities.
- Provide technical support to fisheries agencies in the central and western Pacific.

Conducting fisheries research relies substantially on timely access to high-quality fisheries-dependent data. This involves the identification of data needs and ensuring that these data are collected and made available to the appropriate researchers. To accomplish this, data are acquired from or made available by linking to outside sources or are collected directly by the Honolulu Laboratory. It is important to ensure that the quality and quantity of data meet statistical and analytical requirements. The present market sampling program has been conducted at the Honolulu auction since 1984. The Honolulu auction is the largest public auction for fish and seafood products in Hawaii. It is the central focus of nearly all of the sales activity of the Hawaii longline fleet and the Northwestern Hawaiian Island bottomfish fleet,

both of which fall under federal management. The landings and sales information gathered provides the baseline for monitoring and assessing two of the Council's four FMPs: Pelagics and Bottomfish. The market monitoring frequency has decreased over the years, but on the other hand, the State of Hawaii is taking new steps to acquire information directly from the auction; and it is possible that a reallocation of fishery monitoring priorities might be warranted.

Additional sampling needs outside of the present market monitoring program include collection of NWHI post-harvest lobster size frequencies (both frozen tail and whole live), bottomfish size frequency and landings data from others in the main Hawaiian Islands (MHI bottomfish management) and local troll and handline size frequency and landings data of PMUS (Pelagic FMP issues). As the Laboratory becomes more involved in research on HMS it is likely that additional new sampling programs will be required.

The general approach at the Honolulu Laboratory to fishery monitoring involves NMFS staff contacting fishing vessel captains and operators before and after each fishing trip to provide information important to proper filing of logbooks, species identification, and taking observations the captains may have about fishing conditions and seafood markets. Laboratory staff who collect the logbooks are also involved in shoreside monitoring, data quality control, and report generation. Reports include quarterly reports for the longline fisheries and more detailed and descriptive annual reports on the longline and NWHI fisheries.

The following fisheries are actively monitored:

- Northwestern Hawaiian Islands (NWHI) lobster: Federal logbooks and revenue reports, compiled into an annual report (Pooley and Kawamoto, 1998).

- Hawaii domestic longline: Federal logbook reports issued quarterly and annually (Ito, 1999), and include information from shoreside monitoring of landings and as a Council annual report module.

- American Samoa domestic longline: Federal logbooks (collected in collaboration with the American Samoa fisheries agency and the NMFS Southwest Region office in Pago Pago), compiled in quarterly reports.

- NWHI bottomfish: State of Hawaii logbooks and collaborative shoreside monitoring, compiled into an annual report (Kawamoto, 1999) and as a Council annual report module.

In addition, two specialized reports are prepared:

- U.S. landings in the western Pacific for *Fisheries of the United States*, annually, in collaboration with the NMFS Pacific Islands Area Office (PIAO).

- *Fisheries Statistics of the Western Pacific* (FSWP), annually prepared by WPacFIN from statistics compiled by fisheries agencies in American Samoa, Guam, Hawaii, and the Northern Mariana Islands. Information from FSWP is also used in preparing the bottomfish and pelagic fisheries annual report for the Council.

The Hawaii-based domestic longline logbook program is essentially a census (complete and comprehensive accounting) of trips taken in the fishery because a dockside inventory of vessels operating out of Honolulu can be maintained, although vessels which land in California operate under different rules. Under a data sharing agreement, the Laboratory receives both sets of logbooks which are keypunched in Honolulu and maintained in separate data bases. Electronic data files are returned to California Department of Fish and Game as part of the agreement.

Landings (weights and values) for the Hawaii longline fishery are monitored through shoreside sampling in Honolulu and State of Hawaii commercial catch reports.

The American Samoa *alia* longline logbook program is not directly monitored by the Honolulu Laboratory and evidence from the WPacFIN program indicates that the program has not been comprehensive (see section below). WPacFIN estimates based on creel surveys is that the logbook system underreported by approximately 30-35% in 1998, although many of these trips may have been zero catch or low catch trips. Landings in the American Samoa longline fishery are monitored by WPacFIN (Table 1). The status of the two longline fisheries is reported in an annual publication issued as a Laboratory administrative report.

The NWHI lobster logbook program is also a comprehensive census of trips taken because of the combination of dockside inventory and in-season reporting requirements through the PIAO. In addition, lobster fishing vessel captains are required to file sales reports to NMFS which are compiled by Laboratory staff. The status of the NWHI lobster fishery is reported in an annual Laboratory administrative report.

The more distant portion of the NWHI bottomfish fishery has been under a limited entry program requiring Federal permits since the mid-1980s, while the area just north and west of Kauai will be coming under a limited entry program in mid-1999. The NWHI bottomfish data reporting program involves a, combination of State of Hawaii HDAR commercial logbooks and sales reports for the participants and shoreside monitoring by Laboratory and HDAR staff. The status of the NWHI bottomfish fishery is published annually by Laboratory staff and includes an estimate of the optimal number of vessels in the more distant limited entry zone.

Finally, Laboratory and HDAR staff monitor the Honolulu auction on a twice weekly basis with the objective of providing more detailed size sampling and ex-vessel values of the landings. These data are compiled and used in estimating the landings of the Hawaii-based domestic longline fishery and the NWHI bottomfish fishery and in preparing estimates of stock status. Tissue and specialized measurements are also taken by Honolulu Laboratory staff. The NWHI lobster landings are also sampled for size and sex composition on an as-needed basis. There is no adequate sampling of landings on the neighbor islands, but the WPacFIN program has arrangements with a number of seafood dealers to receive sales receipts electronically, and WPacFIN is working with the State of Hawaii HDAR to implement a statewide seafood dealer reporting system.

Recent Activities

Hawaii Longline Logbook Reporting–Laboratory staff continue to upgrade the quarterly and annual reports on Hawaii domestic longline fishery data to make the information more accessible and more complete. Staff have also worked with various fishing vessel captains on prototypes of electronic logbooks and have experimented with receiving logbook data through email. Summaries are now available on the Laboratory's web site, and 5-degree square (nonconfidential) data are downloadable. [**http://www.nmfs.hawaii.edu/fmpi/fmep/index.htm**]

Hawaii Pelagic Fishery Status Report–Laboratory staff also compile almost the entire Hawaii module for the Council's annual pelagic fishery report, including integration of landings data from all gear types. This provides an unified source of landings estimates for these fisheries.

Hawaii Longline Enforcement Cooperation--Laboratory staff have been working with NMFS Southwest Enforcement in cross-checking logbook numbers with off-loadings in Honolulu harbor. Laboratory staff have trained Enforcement staff in species identification and have participated in monitoring a sample of off-loadings. Enforcement staff have asked the Laboratory for advice on what level of precision is adequate for analytical purposes and a Laboratory analyst has performed a series of GAM (General Additive Models) analyses to the differences between logbook and observer counts of various species and species groups to provide a baseline. This cooperative effort between Enforcement and the Laboratory has already had a noticeable effect in improving the quality of the marlin species identifications, the count of secondary species, and the recording of shark fins.

Hawaii Longline Analysis--Laboratory staff have continued work initiated in the Stock Assessment Investigation to utilize sophisticated statistical programs to analyze and compare longline logbook and observer data. These analyses will provide an improved means for identifying outlier information in the logbooks, working with captains on species identification, and when necessary, alerting Enforcement of specific problems.

American Samoa Longline Fishery Comparisons of Logbook and Creel Data- Comparisons of summary annual data were made between the American Samoa Department of Marine and Wildlife Resource's (DMWR) creel survey and a subset of the logbook census data indicate a fairly high variability in two data sets in terms of "raw" numbers, with the logbook data generally showing underreporting. Comparisons of data on a vessel-by-vessel basis reveal even more variability not obvious in annual summary comparisons. There is, however, less variability in the creel-to-logbook ratio of catch rates, which indicates that the biological indicators of the two data sets may be basically telling a similar story, and part of that story may be a confirmation of underreporting of zero or low-catch trips in the logbooks. Comparing a small subset of data on a set-by-set basis indicated that unexplainable, and unacceptable, differences exist potentially on many of the logbooks or creel survey interview forms (see Table 1).

American Samoa Longline

Comparison of Federal Logbook Data with Creel Survey Estimates

	1996		*1997*		*1998*	
Catch and effort	**Logbook total**	**Creel survey estimate**	**Logbook total**	**Creel survey estimate**	**Logbook total**	**Creel survey estimate**
Vessels	9	13	21	22	26	25
Days fished	531	635	1,491	1,963	1,604	2,359
No. hooks	99,990	153,245	346,108	420,671	457,309	695,976
Albacore	4,028	4,658	11,163	13,171	12,330	14,270
Skipjack	6	44	405	255	1,665	2,840
Yellowfin tuna	645	652	932	1,068	1,112	1,595
Mahimahi	227	201	788	1,200	797	1,290
Wahoo	82	86	311	360	1,005	1,409

Table 1

These comparisons emphasize the importance of moving the responsibility and capability of collecting, processing, and controlling the quality of the Federal logbook data to the DMWR. Having the data processed locally on a real-time basis will facilitate improving the quality of the data through increased cross-validation, fisherman interactions and feedback, and use of local expertise in resolving data issues. NMFS FMEP and WPacFIN staff will continue to provide technical assistance and provide reports on the status of the fishery.

Statistical Analyses of Hawaii Longline Catch Rates and Catch Composition-A series of statistical analyses were conducted with data derived from the logbooks of Hawaii-based commercial longline vessels and from records kept by NMFS fishery observers to improve understanding of patterns of catch composition, to identify factors that influence catch, and to clarify historical trends, particularly with respect to incidental blue shark catch rates. Similar analyses were also conducted to compare the normal variation between logbooks filed by captains and observer records for the same trips as a baseline for enforcing logbook record-keeping for non-observed trips.

A 7-year set (November 1990-October 1997) of logbook data was subjected to cluster analysis. Three clusters were defined on the basis of catches of 12 species. The first cluster, and the most consistent in its catch composition, was dominated by blue shark and swordfish. The second cluster was dominated by bigeye tuna and albacore and the third by swordfish and bigeye tuna. The blue shark/ swordfish cluster was primarily associated with swordfish-directed and mixed-species-directed fishing, whereas the bigeye tuna/albacore cluster was primarily associated with tuna-directed and mixed-species-directed fishing.

GAM and regression tree analyses were conducted with blue shark catch-per-unit-effort data collected aboard Hawaii-based commercial longline vessels by NMFS observers from March1994 through December 1997. Latitude exerted the strongest individual effect, while longitude was the most influential variable when adjusted for the effects of all other factors. Temperature was the most important environmental factor. An adjusted time series plot revealed no apparent trends in blue shark CPUE since 1994.

A GAM of blue shark CPUE was fitted to data gathered from March 1994 through December 1997. This regression indicated that logbook CPUE data varied directly with, but were generally less than, GAM predictions. These results indicated that prediction with a GAM fitted to fishery observer data is a useful monitoring technique for the Hawaii-based commercial longline fishery because it improved insight into fleet-wide and individual logbook reporting practices and permitted estimation of the relationship between logbook data and predicted values, characterization of the bias in this relationship, and identification of patterns specific to each major sector of the fishery.

In the second analysis, statistical research was undertaken to determine and summarize patterns of concurrence between catches reported by fishery observers and logbooks from March 1994, the start of the observer program, through December 1998. Catch data for 15 species taken by the Hawaii-based longline fishery on sets with fishery observers (N = 2,684 longline sets) are being tabulated to determine the percent concurrence between catch records from observers and logbooks and the frequencies of differences of various magnitudes. The confidence limits will be used to prepare tables, which may serve in monitoring as estimates of normal accuracy in relation to catch magnitude and confidence level.

WESTERN PACIFIC FISHERY INFORMATION NETWORK (WPACFIN)

Background

In 1981 WPacFIN was initiated as a formal cooperative agreement among fisheries agencies in the central and western Pacific to improve fishery monitoring and reporting systems to better meet local and federal fishery management needs. The NMFS Honolulu Laboratory program, known as central WPacFIN has strived to develop and implement appropriate and comprehensive data collecting and processing systems in each of the four major Council island areas. Formalizing and standardizing data collecting systems and computerizing the collected data began in the early 1980s. As technology changes, so has WPacFIN's approach, and WPacFIN is now in its second year of implementing major hardware and software upgrades, moving to the Windows 95/98 and Visual FoxPro environments in all agencies. The legacy systems are being significantly redesigned and improved to take advantage of newer technology and become Y2K compliant, to improve data quality, and to reflect changes in the fisheries and in federal reporting requirements.

Many of the island agency fisheries data collecting systems have also changed to improve fisheries monitoring programs and to begin addressing many of the increased informational needs of the local and federal fisheries management organizations within WPacFIN. Changes have been implemented this past year to address data needs to meet new SFA (Sustainable Fisheries Act of 1996) and various FMP Plan Team reporting requirements, such as by catch, fishing sector, charter boat, and recreational fishing data. Plans for implementing more changes are being finalized. The central WPacFIN office assists in identifying these changes and supports the island agencies by developing appropriate data collecting, processing, and reporting systems for the island agencies and helps train the local staff in implementing the changes.

Significance

WPacFIN island agency data systems are the monitoring mainstay of many fisheries in the central and western Pacific and provide information for meeting many Magnuson-Stevens (MS) and SFA requirements. Use of the Internet and development of a web site are improving the availability of WPacFIN data and information.

WPacFIN Goals and Approach

Central WPacFIN

- Coordinates fisheries statistics programs in the region.
- Provides technical computer and biological assistance to island fisheries agencies.
- Provides hardware and software support to these fishery agencies.

- Prepares fishery monitoring and fishery statistics compilation systems, including software development.

- Compiles and disseminates regional fisheries statistics.

Administrative Report H-98-11 (December 1998), *Central Western Pacific Fishery Information Network (WPacFIN) Three-Year Plan*, summarizes the general program areas, support activities, and projects conducted by Central WPacFIN and describes the many system upgrades and changes being implemented in island areas as recommended during the February 1997 WPacFIN Data Workshop 2000.

Recent Regional Activities

Staff Availability

As a major result of PacFIN add-on funds, central WPacFIN maintains an existing support staff for data processing, managing, reporting, analyzing, and coordinating activities, and now has five JIMAR/RCUH computer programmers dedicated to developing software for island agencies plus one programmer dedicated to developing the WPacFIN web site. In addition, the State of Hawaii's fishery agency (HDAR) hired a programmer during the year to work directly with the WPacFIN staff and industry to develop the HDAR Dealer Reporting System.

Computer Hardware and Off-the-Shelf Software Upgrades

All island agencies have now been upgraded to Pentium level computers and Windows 95/98 for their major fisheries data programs and have the latest versions of database and other processing software required by WPacFIN and the various FMP Plan Teams. HDAR has additional WPacFIN and local funds to make further substantial upgrades during the next year.

On-Site Technical Support, Troubleshooting, and Training

Frequent meetings between central WPacFIN and HDAR staff are held to coordinate activities and ensure progress on numerous cooperative projects. By the end of this fiscal year, central WPacFIN staff will have made three on-site visits to each of the "out-island" agencies to perform a wide variety of technical support activities, including assisting with developing report modules for Council Plan Team annual reports, developing specifications for new and improved data collecting and processing systems, investigating and fixing data quality problems, and implementing new data systems and training staff on their use. On-site visits and meetings with local agency staff are critical to making continued improvements to data collecting and processing systems.

Web Site Development

The WPacFIN web site was made "public" this year and continues to grow in content and quality. It currently contains over 5,000 pages, including many photos and graphs documenting island fisheries and data programs and regional fisheries statistics. Making additions and improvements to the existing static pages of data and information is a continuous process, and the next major phase of development will be implementing on-line queries against summary data bases. Only nonconfidential data will be available through the WPacFIN web site (**http://wpacfin.nmfs.hawaii.edu/**).

Recent Island-Specific Activities

State of Hawaii Commercial Fisheries Reporting Systems

WPacFIN has made a major effort since 1996 to upgrade the State of Hawaii's commercial fisheries processing and reporting system, beginning with the development of an integrated logbook and landings reporting system for the federally managed NWHI bottomfish fishery. During the past year, significant progress has been made on four major projects.

- Implementing an integrated Fisherman Reporting System (FRS) for data validation and editing of all existing fisherman-submitted commercial fisheries data forms.

- Developing and implementing the first phases of a Dealer Reporting System (DRS) which is computerizing data submitted by fish dealers throughout the State.

- Modifying all fisherman-submitted forms to improve data on catch, effort, and sales in response to federal suggestions.

- Revising the Commercial Marine Licensing System (CMLS) to improve tracking of vessels and submission of reporting forms by commercial fishers.

WPacFIN staff have also been working with the Hawaii Division of Boating and Ocean Recreation (DBOR) to convert the State's vessel registration system and historical vessel database out of an archaic proprietary legacy system into a modern PC database. Although it appears that much of the historical record has been partially destroyed, this project is laying the foundation for obtaining future vessel database updates from DBOR on a routine basis to enhance HDAR and NMFS data quality control procedures.

American Samoa Department of Marine and Wildlife Resources (DMWR)

Major progress has been made in four areas during the past year.

- Developing new Visual FoxPro (VFP) data processing systems has been the most significant activity in Samoa. New VFP software has been implemented for the Commercial Landings System, Cannery Landings System, Vessel Identification System, and Tournament Sampling System. Major progress has been made on programming the new Offshore Creel Survey System.

- Upgrading the fisherman and vessel coding systems and editing various historical databases by developing a historical vessel database and integrating updates from the Department of Public Safety's Vessel Registration System into the DMWR Vessel Identification System.

- Implementing improvements in the offshore creel survey to collect more complete data to meet new SFA requirements, eliminate sampling bias and to improve the coverage of the fisheries.

- Laying the foundation for improving the NMFS Longline Logbook data from Samoa by moving the responsibilities for collecting, processing, and quality controlling the data to DMWR.

Guam Division of Aquatic and Wildlife Resources (DAWR)

Major emphasis has been on two significant projects at DAWR.

- The shallow-water bottomfish research project, funded primarily by WPacFIN add-on funds, recently completed the field work aspects of the project and now is in the data processing and analysis phase. A sophisticated data processing system was programmed by central WPacFIN staff and is being used by DAWR for data quality control and analysis. A special report summarizing the project will be part of next year's Bottomfish Plan Team annual report.

- The offshore creel survey system has been modified numerous times during the year in response to new requirements discovered during the major undertaking of computerizing and quality controlling all historical data into the new data system.

Guam Department of Commerce (GDOC)

Three major projects have been underway at GDOC.

- A "Notice of Arrival" system was designed, programmed, and implemented to improve data integrity and vessel identification.

- A 2-year project to improve vessel identification and cross-referencing was completed, and all historical databases were updated to reflect the best available information possible.

- Design and programming of several modules of the new VFP data system were completed. This fisheries monitoring system handles the most complex set of interrelated industry forms in WPacFIN.

CNMI Division of Fish and Wildlife (DFW)

Three notable projects were undertaken this year.

- Improving the vessel identification data base by establishing a relationship with the Department of Public Safety (DPS) for routinely obtaining updates of vessel registration data.

- Using WPacFIN add-on funds, the boat-based creel survey is being reinitiated this year following a 2-year gap in CNMI support.

- Expanding data collecting and processing systems to the other two inhabited islands of Tinian and Rota has been under discussion for over a decade, and this is being accomplished this year.

WPacFIN Plans

Much work needs to be done to continue the upgrading of island agencies and the central WPacFIN computer systems to meet fishery management needs and implement programs identified in the 3-year plan. The requirements of the MS and SFA are substantial and will require sizable financial and personnel investments. The increased level of funding that has come through the PacFIN budgeting process is critical in implementing improvements to the data systems. Sufficient funds are not available to meet all of the needs identified in the 3-year plan.

ECONOMIC RESEARCH

Background Information

Economic research at the Honolulu Laboratory over the past 5 years has concentrated on these three areas:

- Pelagic fishing vessel economics.
- NWHI bottomfish vessel economics.
- Theoretical and applied research on alternative fishery management regimes.

With the demise of the SWR/SWFSC socioeconomic research fund in the early 1990s due to budget constraints, all quantitative economic research at the Honolulu Laboratory has been conducted in cooperation with the UH JIMAR Pelagic Fisheries Research Program. The Hawaii Fleet Industry & Vessel Economics project (HIFIVE) has conducted a range of field investigations on the cost-earnings structure of the Hawaii-based domestic longline fishery as well as the Hawaii small boat pelagic fisheries, including trolling, handline, charter boats, and charter fishing patrons. Economic analysis on NWHI bottomfish and lobster issues has relied on data collected in the mid-1980s and early 1990s.

Economic Research and Analysis Objectives and Approach

The Honolulu Laboratory's economic research and analysis objectives are to:

- Conduct baseline research on commercial and recreational fishing, seafood marketing, and related marine activities in the central and western Pacific.
- Provide analysis for fishery and protected species management decision-making.
- Investigate alternative fishery and protected species management regimes for possible future applications.

The approach of the economics research and analysis focuses on supporting Council fishery management plans (FMPs). This involves each objective and provides an integrated platform for the Laboratory's economics work.

Major Research Activities

Regulatory Flexibility Act

The Regulatory Flexibility Act of 1996 (RFA) is the primary legislation driving economic analysis in the current period. It allows judicial review of agency assessments concerning the economic impact of regulations on small businesses, non-profit organizations, and local governments. The NMFS Office

of Sustainable Fisheries (F/SF) has initiated efforts to revise NMFS guidelines on complying with RFA requirements (the Honolulu Laboratory industry economist participates in that working group). In the meantime, however, F/SF has required a greater degree of specificity in terms of identifying the viable alternatives to be considered by the Council and analyzed under RFA. The PIAO economist has been concentrating on the former,[1] while the Honolulu Laboratory has been concentrating on conducting simplified pro forma financial statement analyses for the latter.[2] However the analyses of the regulatory impacts are increasingly based on older cost-earnings information. Present staff and field work resources are simply inadequate to meet the economic data collection requirements of the revised Magnuson-Stevens Act and the RFA requirements. The NMFS socioeconomic initiative has not provided any resources for this kind of work in the central Pacific.

HIFIVE Activities

The Hawaii Fleet Industry & Vessel Economics project (HIFIVE) is part of the University of Hawaii's JIMAR Pelagic Fisheries Research Program and has been funded since program initiation in 1994 under the co-leadership of the Laboratory's industry economist. The purpose of this research project has been to provide fishery management information based on the economic characteristics and dynamics of the Hawaii longline and troll-handline and charter fishing fleets, as well as on the seafood markets and clients of the charter-boat fleets. Some thorough field studies have been completed on the economics of operations for longline (1993 base year), small-boat troll (1996 base year), and charter boats (1997 base year) in Hawaii (these have been published as JIMAR reports). Three major activities during 1999 include the following:

- An economic profile of charter boat patrons in Hawaii–both tourists, big game sports fishers, and local anglers. As part of this activity, a laboratory cooperative JIMAR research assistant has prepared a draft annotated bibliography of recreational fishing studies in Hawaii. This bibliography reviews various articles, papers, technical reports, and other manuscripts addressing selected aspects of Hawaii's noncommercial marine fisheries. The review is intended to meet informational needs of the nascent statewide Recreational Fishing Task Force implemented by the Council toward improved understanding of noncommercial fishing activity and catch reporting in Hawaii's nearshore and offshore waters. Economic and social aspects of the fishery are highlighted, with some attention to its biological aspects but given broad variation in the kinds of materials examined, some breadth of analytical focus is required. In all cases, the review addresses the research methods and analytical techniques used for each project, definitional problematics related to the notion of recreational and other types of fishing, where evident, some general findings, conclusions, and implications of the research as reported by the authors. Hence, the piece is not a critical review of the materials per se, but rather a set of summaries focusing on topics relevant to the informational needs of the emerging Task Force.

[1]Identification and analysis of alternatives are likely to expand in importance to include broader biological and ecological analysis by Laboratory scientists under National Environmental Policy Act (NEPA) regulations.

[2]These analyses are likely to require Center Director certification as are other Laboratory contributions to the Council process as greater emphasis is placed on the administrative record behind Council decisions (as exemplified by the concerns about the overfishing definitions under SFA amendments).

- An analysis of the seafood markets for pelagics in Hawaii (1994-96 monthly and 1996 weekly data). This study, conducted by JIMAR economics researcher Minling Pan, analyzes the price relationships in the Hawaii pelagic seafood market. Particular attention is paid to examine the factors affecting price variations in the short run, using the Hawaii Division of Aquatic Resources(HDAR) commercial catch and sales report data in monthly and weekly increments for 1994-96. The study concludes that seasonal variation in the volume of landings by Hawaii-based vessels is the predominant factor affecting variation in price for the most of the pelagic species, but price variation is less than volume variation. Substitutability effects are found within certain species groups that have similar end uses. Holidays (Christmas and New Year's) and the number of tourists coming from Asia are also associated with variation in bigeye and yellowfin tuna prices. In addition, the quality of bigeye appears to have a seasonal pattern that is strongly correlated with sea surface temperature and thus in-seasonal variation in bigeye tuna prices (Fig. 1).

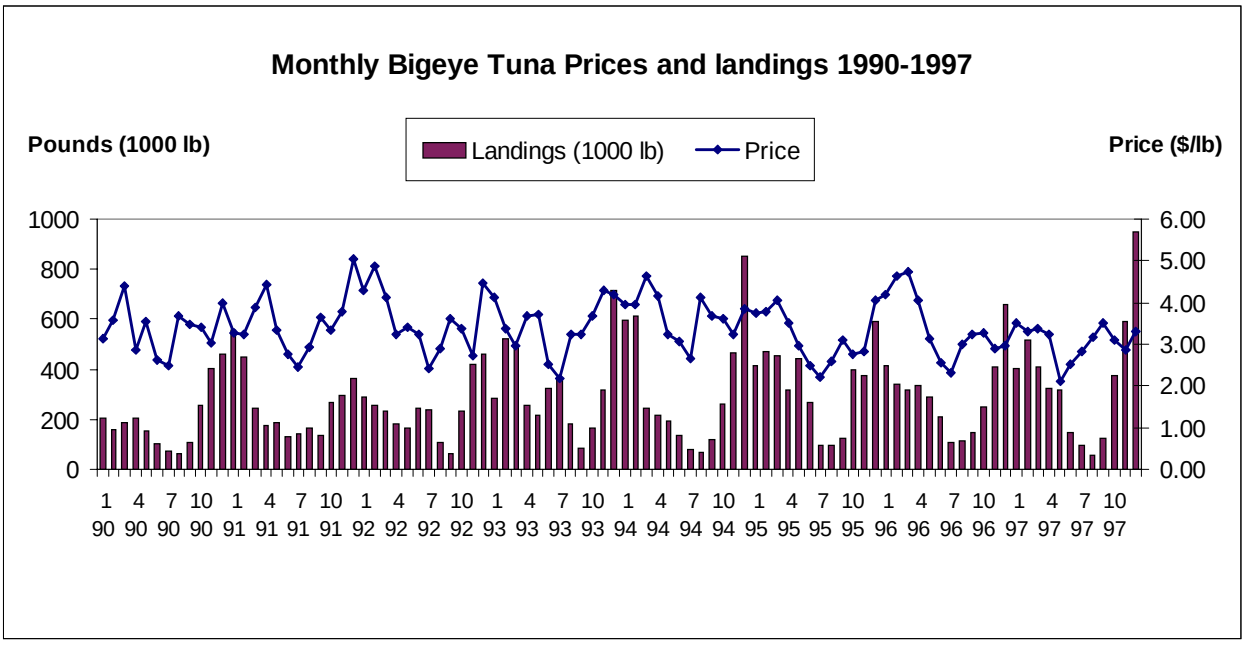


Figure 1: Seafood markets price dynamics for bigeye tuna in Hawaii (1994-96 monthly), Hawaii Division of Aquatic Resources (HDAR) commercial catch reports. Compiled by JIMAR economics researcher, Min Ling Pan, as part of the HIFIVE research project.

- A study of the economic production dynamics of each of the pelagic fishing fleets in Hawaii (further analysis of the cost-earnings information from previous years' research). This research has just begun and will be the focus of HIFIVE economic research through 1999.

- These studies will collectively provide a comprehensive picture of the economics of pelagic fishing in Hawaii and provide information to decision-makers on the impact of regulations on the performance of fishing businesses, recreational anglers, and seafood consumers.

Alternative Regulatory Regimes

The Laboratory economist has undertaken theoretical research on a range of alternative regulatory regimes based on the property-rights approach to fisheries management. Some of this work

has been published under the first authorship of colleague Professor Ralph Townsend of the University of Maine concerning corporate approaches to commercial fisheries management (specifically for the NWHI lobster fishery). Other work, focusing on nonprofit corporate approaches for community control of fisheries has been published or presented to international conferences by the Laboratory's industry economist. These works may be applicable to the Council's community development programs although that arena may be potentially politically sensitive.

PIAO NWHI Lobster Study

FMEP staff have also cooperated with two PIAO studies this year: one on shark utilization and another on the NWHI lobster fishery bycatch. The latter project will also provide detailed information on lobster fishing operations and badly needed updates of cost-earnings information for the NWHI lobster fleet. This study is being conducted by Professor Ralph Townsend of the University of Maine who has collaborated with the Laboratory's economic research program in the past.

Academic Activities

Sam Pooley, Laboratory industry economist, has been reappointed as affiliate graduate faculty to the University of Hawaii's Department of Agricultural & Resource Economics and appointed for the first time to the University's Department of Political Science. He continues to serve on the University's Ocean Policy Faculty and has been asked to serve as an external advisor to a new think tank on campus concerning the impacts of globalization on Hawaii. He continues to serve as a contributing editor to *Marine Resource Economics*.

Staff Advances

The two JIMAR cooperating social science researchers have both made substantial progress at the University of Hawaii. Minling Pan received her doctorate in Agricultural and Resource economics this winter based on a fisheries maximization model supported by another PFRP project and in conjunction with the Laboratory's industry economist. In addition, Edward Glazier has initiated his doctoral research in Sociology utilizing information compiled in an earlier PFRP project and his current recreational fisheries research in the HIFIVE project. Finally, former HIFIVE JIMAR research associates have also thrived. Dr. Michael Travis took an economics position with the NMFS Southeast Region. Dr. Rita Curtis received her doctorate at the University of Maryland based on her HIFIVE longline dynamics research and has taken a position with the Sustainable Fisheries Office in NMFS Headquarters. Finally Ms. Marcia Hamilton has taken a position with PIAO and is enrolled as a doctoral student at the University of Hawaii's Department of Geography utilizing information collected during her HIFIVE research tenure.

HIGHLY MIGRATORY SPECIES

Background Information

The mission of the Honolulu Laboratory includes providing scientific support for management decisions on fisheries for tunas, billfishes, and other highly migratory pelagic species in the Pacific. The Laboratory conducts pelagic resource stock assessments and the biological and oceanographic research needed to improve stock assessment and management analysis. The Laboratory's findings are provided to the Council and PIAO and are major ingredients of the Council's FMP for pelagics. The Laboratory's research also provides support for multilateral assessment of pelagic resources and the participation of the U.S. in the emerging international arrangements for HMS fishery management in the central and Western Pacific (MHLC) and for scientific cooperation on HMS in the North Pacific (ISC).

The scope of the Honolulu Laboratory's pelagics research is defined by the important issues faced by the Council and the international fisheries community. Currently these include concerns about the status of swordfish targeted by Hawaii's longline fleet and the blue marlin population important to Hawaii's recreational and charter-boat troll fleet. They also include concerns about the effects of longline fisheries, including Hawaii's fishery, on shark populations. Of secondary concern are the status of tuna populations important to U.S. fisheries and also exploited by foreign fleets, and populations of other pelagic species about which little is known; e.g., ono, opah, and mahimahi.

Goals and Objectives

- Provide scientific support and advice to the Council, NMFS managers, U.S. State Department, and other agencies and organizations regarding the status of pelagic fish stocks in the Pacific and related fishery management issues.

- Conduct the scientific research and analysis required to provide such support.

Major Research Activities

During FY 1999, Honolulu Laboratory staff and affiliated JIMAR scientists conducted research on a range of topics concerning pelagic resources, including swordfish, blue shark, and bigeye tuna.

Swordfish

ISC Swordfish Working Group--A meeting of the Swordfish Working Group (SFWG) of the ISC was convened in Honolulu, Hawaii, January 15-16, 1999. Twenty-seven persons participated, including, scientists from ISC member countries Japan, Mexico, and the United States; National Taiwan University; the Overseas Fisheries Development Council of the People's Republic of China; the Inter-American Tropical Tuna Commission; the Secretariat of the Pacific Community; and other organizations. R. Michael Laurs (U.S.), Director of the Honolulu Laboratory, chaired the meeting. The purpose of the

meeting was to review information concerning swordfish resources in the ISC region of interest, including fishery statistics, the status of swordfish stocks, and progress in biological and oceanographic research in support of swordfish stock assessment. Ten working papers were presented and discussed.

Despite considerable progress in research on swordfish biology and fishery oceanography and extensive sharing of historical fishery statistics for the purpose of swordfish stock assessment, provisional stock assessments presented by SFWG scientists were inconclusive. The degree of exploitation and condition of the resource could not be determined and remain unknown. However, the working group noted that the standardized swordfish catch-per-unit-of-effort (CPUE) in the Japanese longline fishery has been stable at least since the mid-1970s, by which time Japanese longline fishing effort was broadly distributed over the region, and has been directly and linearly related to the total swordfish catch. Assuming that CPUE reflects swordfish abundance, these facts are consistent with a low exploitation rate.

The SFWG identified several critical needs in fishery monitoring and biological and oceanographic research to improve models of swordfish population dynamics and reduce uncertainties in stock assessments. These research needs were organized into a recommended SFWG Work Plan for consideration by the ISC Plenary. The ISC Plenary adopted the Work Plan, noting that its execution will require vigorous support of all concerned parties. Specific research topics in biology, oceanography, modeling, and fishery monitoring were organized under the following focus areas:

- Develop and apply spatially explicit assessment models.
- Account for factors affecting CPUE.
- Develop capability for age-structured stock assessment models.
- Develop and apply basin-scale simulation model.
- Develop comprehensive swordfish fishery database.

To ensure that critical research tasks are accomplished, the work plan identifies SFWG scientists who expressed interest in collaboration on specific projects. These scientists would be expected to initiate follow-up action, including development of work plan details (e.g., timetables, data sharing arrangement, etc.) through coordination with other interested scientists. The next meeting of the SFWG will be convened just prior to the third meeting of the ISC, tentatively scheduled for FY 2001.

Swordfish Stock Assessment--A data exchange with Japanese colleagues was arranged with the long-term aim to develop and apply assessment models that could address the complex spatial dynamics of swordfish populations in the Pacific and of the various fisheries that exploit them. A short-term proviso of that exchange was to conduct a preliminary stock assessment with more traditional, spatially aggregated models, and to present the results at the SFWG meeting January 15-16, 1999.

Two production models were developed and applied to combine Japanese and Hawaiian longline catch and effort data for the North Pacific west of 135°E and north of 15°N. Allowance was made for catch by Taiwanese and Korean vessels for which complete effort data were lacking. One model is a traditional Pella-Tomlinson production model with a non-traditional feature of allowing constrained variation in time of catchability and carrying capacity. The second model partitions fish production into parameters of recruitment and natural mortality with constrained variation in catchability and recruitment. The results were presented as a working paper to the SWG meeting in January 1999. Both models gave equivocal results in that with slight changes in weighting factors they converged to different scenarios varying from high population turnover with scant effect of the fisheries to slow turnover with large effect of the fisheries, though no scenarios implied impending population collapse. The most interesting result is that these relatively simple models gave indications of difficulty in dealing with the changing spatial extent of the fisheries.

The work on these models and deliberations concerning them at the SWG meeting contributed to launching the SWG on a new cycle of research activity to collect the requisite data and to develop the requisite models to address the dynamic spatial complexities of the swordfish population and fisheries.

Swordfish Biology--The Honolulu Laboratory's biological studies of swordfish in FY 1999 have continued the recent (FY 1997-98) emphasis on age- and growth-related topics. Major effort has been directed at expanding the scope (number of specimens) of swordfish aged to a production level and continuing to validate age estimates. A conventional tagging program whose goals are to describe fish movements and provide growth-at-liberty estimates has continued. Work on the development of markers to identify the sex of commercially caught swordfish, indistinguishable by conventional means because fish are landed headed and fully gutted in the Hawaii-based pelagic longline fishery, have continued with NGO collaborators. Our final major objective remains to provide, by the end of FY 2000, accurate and precise sex-specific estimates of size-at-age, growth rate, and age-specific maturity.

Growth Studies--Age and growth studies of swordfish continue to utilize the information provided by "annuli" (bands formed once yearly) on cross sections of anal fin rays. Preparation and analyses of anal fin ray cross sections have continued for swordfish spanning the entire range of body sizes exploited by the Hawaii-based pelagic longline fishery (from about 70- to more than 250-cm eye-to-fork length, EFL). First readings and measurements have now been completed for a cumulative total of 1,400 fish using the light microscope and about 1,000 fish using a digital image analyzer. A substudy to characterize within- and between-reader ageing errors has been initiated, as have specimen exchanges with other institutions to distinguish possible differences in ageing protocols from potential variations in growth rates among North Pacific regions (e.g., for swordfish caught by the Taiwan- and Hawaii-based longline fisheries). Specimen and protocol exchanges have been initiated with Drs. Sun at the University of Taiwan and Sosa-Nishizaki at the Centro de Investigacion Cientifica y de Educacion Superior de Ensenada (CICESE).

An important ageing study, complementary to our primary study estimating the ages of large numbers of swordfish using fin rays, has been an evaluation of the age record provided by earstones (otolith sagittae), a second ageing tissue or "hard part." The major emphasis here has been a matched comparison of the estimated body sizes at age 365 days as indicated by daily growth increments (DGIs) on earstones and at age-1 year from annuli on fin rays. To date, counts of DGIs have been completed for a total of 40 young-of-the-year (YOY) and yearling swordfish. Length at age-365 days has been estimated as 98 cm EFL (95% confidence limits, CI = 93-103 cm EFL) based on DGIs. This estimate compares favorably with that at age-1 year based on fin rays, for which our best current estimate is 95 cm EFL (95% CI = 92-98 cm EFL). Growth rates of YOY-yearlings based on earstones thus validate our fin ray estimates of early growth. Limited (n = 3) recaptures of tagged yearling fish at liberty for 1, 2 and 4 years further indicate that our characterization of length-at-age is reasonable (Fig. 1) for fish of this size and age range. Data for both sexes pooled are depicted in Figure 1, even though male swordfish mature earlier, grow more slowly, and do not live as long as females because sexes of the recaptured fish are unknown. Also, the simplistic (von Bertalanffy) growth model illustrated in Figure 1 does not fully describe the relatively rapid growth of YOY. Subsequent-generation characterizations need fit more complex and realistic generalized growth models for the sexes separately. We emphasize that sex-specific estimates of growth as well as age-at-maturity distributions are essential elements of future age-structured stock assessments for swordfish in the Pacific.

Conventional Tagging Studies--The tagging of swordfish and other pelagic fishes continued this past year, aided by both contracted and cooperative arrangements with commercial longliners and resulted in newly tagged totals of 93 swordfish, 37 tunas, and 2 marlins. Fifteen sharks of 3 species (10

blue, 2 mako, 3 bigeye thresher) were also tagged in support of the shark research program of the Pelagic Resources Division of the National Research Institute of Far Seas Fisheries (NRIFSIF), Japan. Ninety-two sharks have been tagged and released within the region of the Hawaii-based fishery since the shark tagging program was begun in 1997.

Since the beginning of the Honolulu Laboratory's pelagic fish tagging program in 1990, cumulative totals of 556 swordfish, 155 marlins (blue and striped marlin, shortbill spearfish) and 218 tunas (albacore, bigeye, and yellowfin tunas) have been tagged. To date there have been 46 tag recoveries (3 swordfish, 8 blue and 30 striped marlin, 5 bigeye tuna) by the Hawaii-based pelagic longline fishery and United Fishing Agency, Honolulu. Two additional swordfish recaptures have been made by other fisheries (Japanese longliner, California drift netter). The Hawaii recreational fishery has recovered about 20 tagged billfish (14 blue and 56 striped marlin), and Hawaii-based longliners recently recovered four tagged blue sharks. Three of the five swordfish recaptures have provided some of the growth-at-liberty data needed to validate growth rate estimates (see Fig. 1).

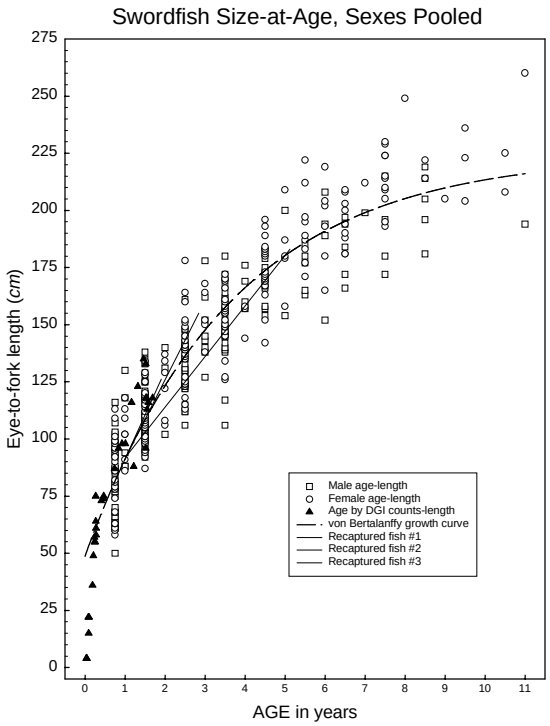


Figure 1.

Morphological, Chemical, and Genetic Proxies of Sexual Identity--Size composition data for known-sex swordfish caught by the Hawaii-based pelagic longline fishery during 1994-97 suggest that sex ratio can be adequately predicted from body length for fish between about 100 and 220 cm EFL (Fig. 2). A spatially and temporally refined version of this mathematical relationship might be applicable to the entire Hawaii-based longline fishery. If so, data on body size could be used as a morphological proxy for sex that would allow swordfish landings data to be partitioned by sex based on size composition. Sex-specific catch data are necessary if the power of sex-specific age-at-maturity and growth rate data are to be fully utilized in future age-structured stock assessments.

Development of a chemical sex marker has also continued in FY 1999. Results to date of an ongoing attempt to develop a monoclonal antibody (mAB) assay of swordfish vitellogenin (VTG, a protein precursor of egg yolk) have been encouraging. A mAB assay to egg yolk vitellogenin has been successfully developed by Dr. Nancy Denslow, University of Florida, Gainesville, using the frozen ovaries of a large female swordfish longlined on a *Townsend Cromwell* research cruise to the equatorial Pacific in August 1998. The mAB developed has proven capable of recognizing the presence of VTG in (hence the sex of) muscle tissues of known-sex individuals of several other fish species, and cold storage of tissues for several weeks does not appreciably reduce the sensitivity of the assay. The assay is now being evaluated for its ability to distinguish between the muscle tissues of immature and mature male and female swordfish. Practical application of the assay would likely cost about US$15 per fish. If the assay proves capable of consistently identifying the sex of individuals, its greatest value may lie in

the ability to identify the sex of large swordfish individuals from muscle biopsies when tagged and to aid in the subsequent interpretation of movements and other activity data that surely differ among different-sized swordfish of the two sexes.

Collection of tissue specimens for a PFRP grant, whose objective is to develop genetic sex markers of swordfish, was recently initiated as a collaboration with the Hawaii Institute of Marine Biology (HIMB). This PFRP study would complement the University of Florida study in developing a genetic, not chemical (VTG), sex marker for swordfish. Like the chemical sex marker, a genetic sex marker would facilitate identification of the sex of individual fish and have its greatest importance in tagging and tracking studies.

Swordfish Fishery Oceanography--Developing an understanding of swordfish habitat has been and continues to be a research focus for Honolulu Laboratory scientists. Assessment of swordfish distribution and abundance patterns based on fishery data together with environmental information gathered from multiple-platforms (e.g., shipboard surveys and satellite remote sensing) has led to an oceanographic characterization of this habitat (see Essential Fish Habitat section).

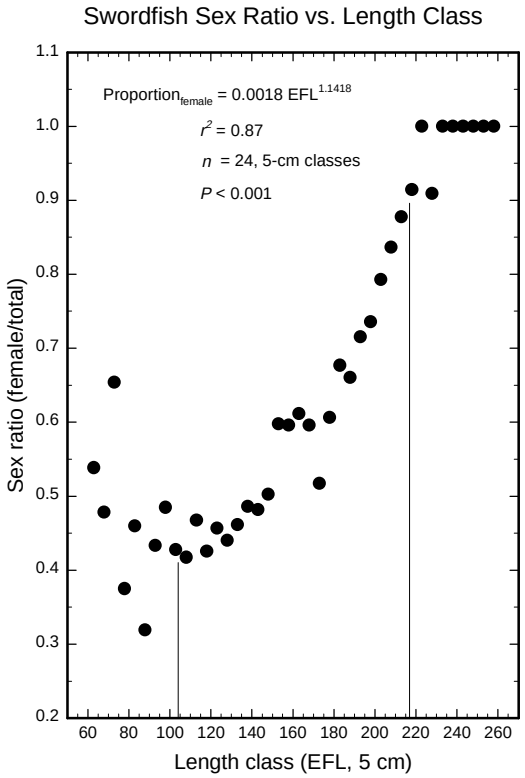


Figure 2.

Swordfish Fishery Simulation Model–By contrast to several tuna species, relatively little is known about swordfish, and the associated time series of catch and effort statistics tends to be characterized by an even greater level of uncertainty and incompleteness. This uncertainty precludes fishery agencies from relying on conventional stock status indicators, so there is a need to identify alternative reference points for management purposes. To design assessment methods that make optimal use of deficient data sets, and determine the reliability and cost-effectiveness of alternative indicators, one usually has to compare the performance of conventional and new analytical tools using known benchmarks.

With this approach in mind, an operational model is being constructed to help evaluate the performance of stock assessment and fishery management procedures in this 'data poor' context. The model is designed to mimic key aspects of the dynamics of pelagic fisheries, as well as the fishery monitoring and management processes. Efforts are being made to structure the model according to the state-space principles described by Schnute (1994)[1]. This framework is well suited for the development of sequential fisheries models, and can be used for simulation and estimation purposes.

The current version is designed to generate time series of fishery or stock attributes given a set of input parameter values, and user-specified sampling patterns and observation error (Fig. 3). The model incorporates key features of aged structured and length-based models and already accounts for the processes of growth, reproduction, mortality, recruitment, and exploitation. Work is in progress to incorporate movement, species interactions, fleet dynamics, and environmental effects. The model

should be sufficiently complete for initial use within the next 6 months, and will be improved as new information is obtained through ongoing studies and data collection programs.

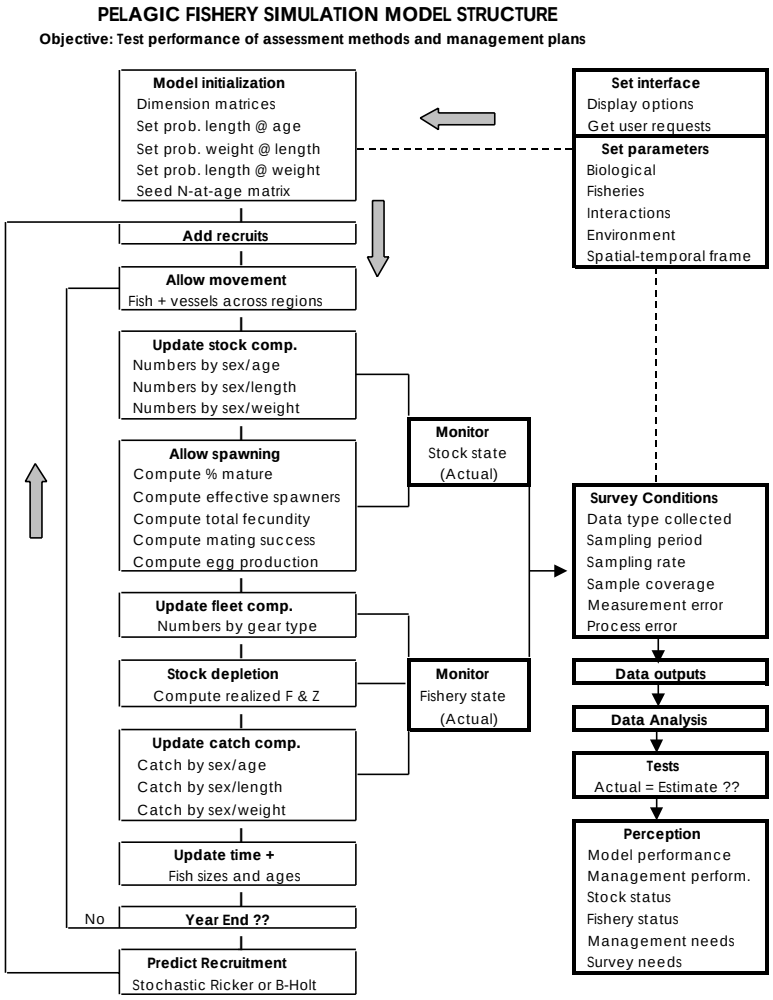


Figure 3.

Blue Shark

Sharks are frequently caught in the Hawaii longline fishery as non-target species or bycatch. The Council's Pelagics FMP includes sharks in its list of affected species, yet there is an insufficient understanding of shark population dynamics and biology to support a meaningful analysis of fishery impacts on sharks and shark management policies. To increase the Council's ability to manage shark fishing mortality domestically and to develop effective multilateral management measures, the Honolulu Laboratory has undertaken several studies on shark fishery statistics, biology, and stock assessment with emphasis on the blue shark, *Prionace glauca,* which makes up over 95 percent of the Hawaii longline shark catch.

To provide a sound foundation for shark biological research and stock assessment, the Honolulu Laboratory established a cooperative research program with scientists at the National Research Institute of Far Seas Fisheries (NRIFSF) in Shimizu, Japan, September 1997. The program has involved exchanges of information and fishery data pertinent to shark assessment and biology and, during FY 1998, a 3-month visit to the Honolulu Laboratory by Dr. Hideki Nakano, a shark specialist with the NRIFSF. As part of the HL-NRIFSF cooperation several accomplishments may be noted as follow:

- A synopsis of biological data on the blue shark has been drafted for publication in a peer-reviewed journal. The synopsis is global in scope and covers blue shark systematics, biology and life history, population status, and exploitation. Publication is expected in 1999.

- Significant progress was also made in the translation from Japanese to English of Dr. Nakano's Ph.D. dissertation on blue sharks.

[1]Schnute, J. T. 1994. A general framework for developing sequential fisheries model. Can. J. Fish. Aquat. Sci., 51:1676-1688.

- Joint research on blue shark population assessment in the North Pacific has begun with the exchange of relevant historical fishery data. Significant effort will be devoted to this project during FY 2000. In addition, progress is expected during FY 2000 with development of a blue shark population simulation model, as much of the computer code for the model will be derived from the rapidly developing simulation model for swordfish.

- Notable progress has also been made in an HL-NRIFSF project to tag and release blue sharks on an opportunistic basis from commercial longline vessels and research vessels; several sharks tagged in the Japanese longline fishery have been recaptured in the Hawaii fishery, and vice versa. (See section on Conventional Tagging Studies.)

In addition to the progress in biological and assessment research, significant strides have been made in the understanding of blue shark fishery statistics in the Hawaii longline fishery with major support from a recently concluded JIMAR/PFRP project. To better understand factors affecting blue shark catches by the Hawaii longline fishery, statistical analyses were conducted using data gathered by NMFS observers from March 1994 through December 1997 and logbook statistics reported by commercial vessels during this period. The first objective was to identify and characterize the statistical relationships between environmental, operational, and temporal factors and blue shark CPUE. This was done by developing a generalized additive model (GAM) and a regression tree model from the fishery observer data. Both models identified a similar suite of predictors of blue shark CPUE and provided complementary interpretations of the data. Both models identified temporal factors as having a statistically significant effect on blue shark CPUE, and the regression tree indicated that month of fishing was the principal source of variation in CPUE, whereas interannual variation in CPUE was not significant over the 4 year period of study.

The second objective of the statistical study was to estimate the expected blue shark catch on each longline set for the 95% of longline trips on which observers were not deployed, given the prevailing operational, temporal, and environmental conditions. The estimated values were computed by treating the fitted GAM as a 'surrogate observer' and applying it to the operational, environmental, and temporal predictor variables as reported in the logbook records for each set. The estimated catch for each longline set can then be compared with the catch reported in the logbooks to identify possible reporting errors and provide a better understanding of reporting (and underreporting) of blue shark catches.

Finally, staff of the Fishery Monitoring and Performance Investigation have continued to monitor the catch of shark in the Hawaii longline fishery and provide statistics on trends in shark catch and utilization to the Council and others. Such statistics are essential to informed decisions by the Council on shark catch and bycatch issues in the Hawaii fishery. An issue of particular importance is the practice of shark finning: processing a shark by removing and retaining its economically valuable fins and discarding the rest of the fish. The NMFS statistics show that the fishery catches about 100,000 sharks each year, of which about 95% are blue shark. In the early part of this decade, most of the sharks were caught on fishing trips targeting swordfish exclusively, but in recent years the majority of sharks have been taken on trips in which the vessel targeted only tuna or those on which either tuna or swordfish might be pursued ("mixed" trips) (Fig. 4). Similarly, there has been a trend toward increased utilization of the shark catch, with the overall percentage of sharks processed by finning rising from 3% in 1991 to 60% in 1998. The highest rate of finning occurs on trips targeting tuna (Fig. 5).

Bigeye Tuna

Archival Tagging–In FY 1999, Honolulu Laboratory scientists made significant strides in research on the behavior and physiology of tunas important to pelagic fisheries in the NMFS Southwest

Region and throughout the Pacific. The research is focused on describing biological characteristics of tunas that determine their distribution and behavior in a dynamic ocean environment and their availability, vulnerability, and catchability to pelagic fishing gear.

In Hawaii, growing troll and handline fisheries, targeting mostly juvenile bigeye tuna at Cross Seamount and around NOAA weather buoys, have created concerns about possible deleterious interactions between these fishing fleets and the effects of the fisheries on the status of the local tuna resource. As a result, the Honolulu Laboratory and JIMAR's PFRP have begun a joint project using archival tags to discern movement patterns and residence times of bigeye tuna near the Hawaiian Islands. To date, 50 archival tags have been deployed near the western coast of the Island of Hawaii (ca. 19°N, 156°W) on fish ranging in size from 54 to 133 cm fork length.

On July 2, 1998, a bigeye tuna carrying an intramuscularly implanted archival tag was recaptured after 85 days at liberty. Ambient light measurements by the tag were expected to provide an estimate of longitude (from local noon) and latitude (from day length) of the tuna's swimming location. Unfortunately because the fish dove so deep during the day (> 450 m), ambient light levels were below the sensitivity of the tag's light detector. However, the fish's daily behaviors were found to be highly repetitive. It remained at 20-90 m at night and dove to 350-500 m each day. This pattern became regular and obvious approximately 6 days after the tuna was released. We were, therefore, able to use the fish's diving behavior to estimate dawn and sunset times and thus calculate its position. From these data, we conclude that the fish remained adjacent to the west coast of the Island of Hawaii for the entire 85 days.

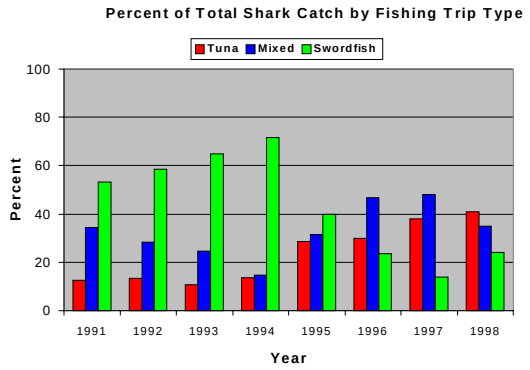


Figure 4.

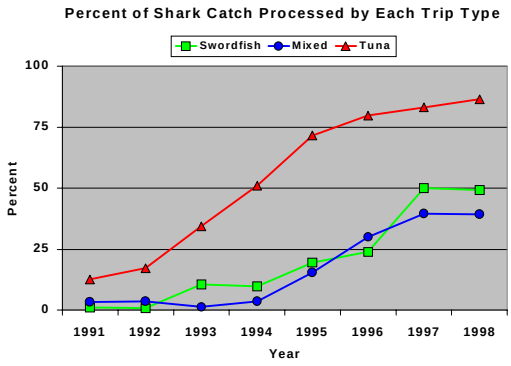


Figure 5.

During this period the tuna's latitudinal movement ranged only from approximately 15°N to 20°N, and longitudinal movement from 155°W to 158°W. (Fig. 6).

During the deep daytime descents when the tuna's body temperature cooled to 17°C, the fish ascended to the warmer surface layer of the ocean (25°C) about hourly in a clearly thermoregulatory behavior (Fig. 7). The ambient oxygen level encountered during the deepest descents was estimated to be only 1 mg l^{-1}. Depths occupied by the tuna during the night were found to be linked to the lunar cycle. During full moon periods the fish stayed around 90 m, whereas during the new moon it came to within 20 m of the sea surface. These observations lead to the hypothesis that the fish's moon phase-correlated behavior is linked to movements of the organisms comprising the deep scattering layer on which the bigeye tuna could be feeding. An understanding of such behavior and its causes will help explain the variability in tuna CPUE in pelagic fisheries, a critical requirement for reliable stock assessments.

An additional 20 conventional archival tags will be deployed during FY 2000. In addition, new pop-up satellite archival tags are becoming available and prototypes of these devices will be tested this year and eventually deployed on bigeye tuna and swordfish as funding becomes available.

Tuna Physiology, Biochemistry and Ultrasonic Telemetry

Population assessments based on CPUE data often assume catchability of the target species is constant; i.e., changes in CPUE reflect changes in overall fish abundance. Accurate population assessments therefore depend on the ability to differentiate CPUE variations linked to abundance from those caused by other factors, such as changes in oceanographic conditions that in turn affect the vulnerability of the fish to fishing gear. Thus accurate stock assessment of tunas depends on understanding how their vertical movements and depth distributions (i.e., their specific gear vulnerability) are affected by oceanographic conditions. This is the focus of research conducted at the Honolulu Laboratory's Kewalo Research Facility. The laboratory research complements field studies of the movements of fish in the open ocean conducted using both ultrasonic telemetry and archival tags.

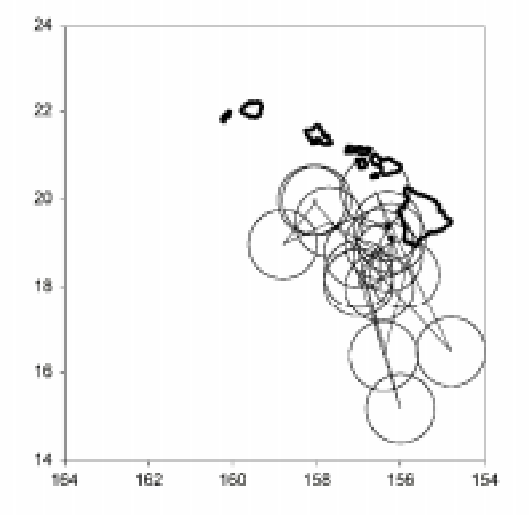


Figure 6. Movements of a bigeye tuna carrying an archival tag over approximately 3 months at liberty. The circles show the estimated uncertainty of position stimates.

A 4-year cooperative Honolulu Laboratory-JIMAR/ PFRP project has resulted in significant advancements in our understanding of factors limiting the vertical distribution of skipjack, yellowfin, and bigeye tunas, including the previously unsuspected influence of temperature on heart function and a resulting limiting effect of ambient temperature on depth distribution (Fig. 8). These studies are already adding significantly to models capable of improving population assessments by accounting for variation in gear vulnerability (e.g., current IATTC and SPC population assessment models for blue marlin, and bigeye and yellowfin tunas). Moreover, this work will directly complement proposed ultrasonic tracking, archival tagging, and a JIMAR-funded fisheries oceanography study of bigeye tuna. Current efforts are directed at understanding the physiological basis for the bigeye tuna's tremendous vertical mobility, in comparison to the relatively limited vertical mobility of other tuna and billfish species. Subject to additional funding, the tagging, physiological, and biochemical research may be expanded to address questions of post-release mortality of blue marlin and bluefin tuna and to measure age and growth parameters useful for developing initial MSY estimates for the little studied incidental species taken by the longline fishery (e.g., opah, ono, and monchong).

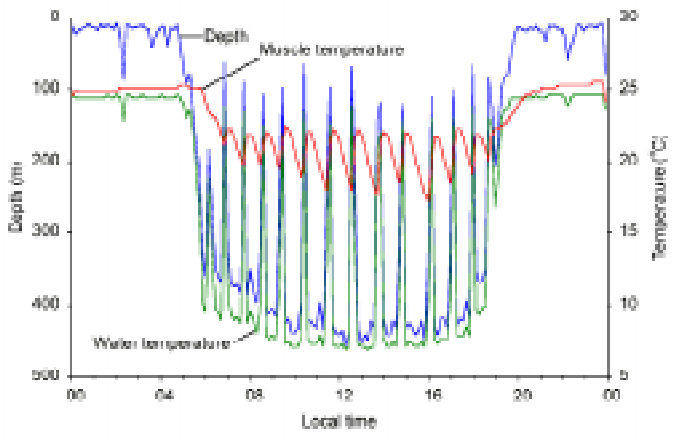


Figure 7. Typical muscle temperature, water temperature, and swimming depth records of a bigeye tuna over a 24-h period. The data shown are from midnight to midnight (Hawaiian standard time). The influence of sunrise (06:30) and sunset (19:30) on the fish's vertical movements can be clearly seen.

Blue Marlin

The Council has raised concerns about the status of Pacific blue marlin and the lack of recent blue marlin stock assessments. Similar concerns have been expressed by other agencies and representatives of recreational fishing constituents throughout the Pacific, not only about blue marlin but other marlin species as well. Accordingly, at the recent meeting of the ISC, it was agreed that an ISC Marlin Working Group (MWG) would be established with the United States having the lead responsibility. The issue or marlin resource assessment is also of considerable interest to the Billfish and Bycatch Research Group (BBRG), a subsidiary body of the SPC's Standing Committee on Tuna and Billfish. The Honolulu Laboratory will organize the SWG and establish a joint research plan. The SWG's activities will be conducted in cooperation with members of the BBRG and other collaborating scientists and agencies.

As the first priority, the Honolulu Laboratory will assess the status of blue marlin, taking into account recent blue marlin research, including analyses of blue marlin stock trends currently underway by the NRIFSF and a stock assessment recently conducted and reported by the IATTC. The IATTC assessment was based on different methods and assumptions from those employed by NRIFSF scientists. The results of the two analyses conflict, one showing an increasing trend in the blue marlin abundance and the other a decreasing trend over the past two decades. The Honolulu Laboratory will work in collaboration with the NRIFSF, other MWG members and others to review both studies, attempt to resolve the differences, and develop alternative models or approaches as appropriate. The short-term objective of the work will be to advise the Council on the current understanding of blue marlin stock status. The longer term goal is to identify shortcomings of blue marlin stock assessments and the research required to overcome them.

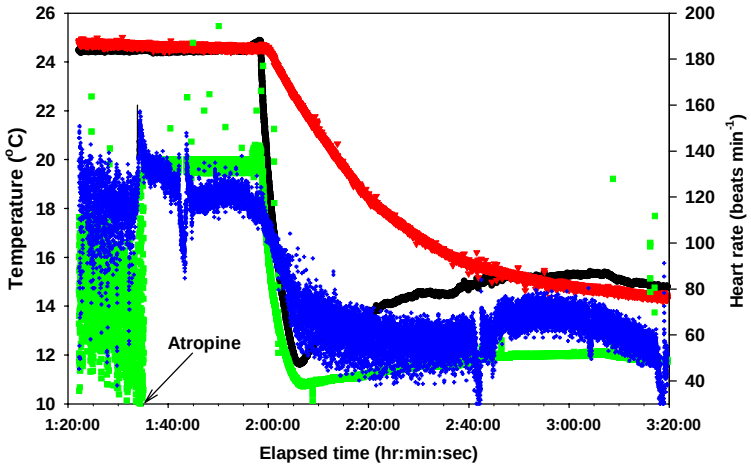


Figure 8. Effects of atropine and abrupt change in water temperature (25° C to 15° C; red) on heart rate (green) and cardiac output (blue) in a yellowfin tuna. (Atropine removes the normal neural control of heat rate and so both heart rate and cardiac output are maximal under all conditions.) Note that heart rate and cardiac output follow the change in water temperature, not the change in muscle temperature (black), which lags significantly behind. These data clearly imply that yellowfin tuna at 15°C have no ability to increase their heart rate and cardiac output and support the hypothesis that the effects of temperature on heart function is a prime determinant of the vertical movements and depth distribution of tunas.

INSULAR RESOURCES

Background Information

Crustacean fisheries within the U.S. EEZ in the Western Pacific are managed under the Council's Crustaceans FMP. The Council is responsible for the development of the Crustaceans FMP; NMFS is responsible for stewardship of the resources and review and implementation of the proposed management actions. Most crustacean landings come from the Northwestern Hawaiian Islands (NWHI) commercial lobster trap fishery which commenced in 1977 and which primarily harvests two species: spiny lobster (*Panulirus marginatus*) and slipper lobster (*Scyllarides squammosus*). Three other species, green spiny lobster (*P. penicillatus*), ridgeback slipper lobster (*S. haanii*), and Chinese slipper lobster (*Parribacus antarcticus*) are caught in low abundance.

The bottomfish fishery in the Hawaiian Archipelago is a multispecies, deepwater (100-400 m), hook-and-line fishery operating primarily from small (5-20 m) boats. The primary species are four eteline snappers (onaga *Etelis coruscans*, ehu *E. carbunculus*, opakapaka *Pristipomoides filamentosus*, uku *Aprion virescens*) and a grouper (Hapuupuu *Epinephelus quernus*), which together account for approximately 78% of the landings by weight (1984-97 average of all fishing areas). Several other species of snappers and jacks make up the remainder of the landings. The NWHI bottomfish fishery is presently limited entry and under federal management jurisdiction. The main Hawaiian Islands (MHI) bottomfish fishery is primarily under State of Hawaii jurisdiction.

Goals and Objectives of the NMFS Honolulu Laboratory Insular Program

The NMFS Honolulu Laboratory has been conducting research on NWHI lobster and bottomfish stocks since the 1970s. The goals of this insular research program are to provide scientific information and advice in support of the Council Crustaceans and Bottomfish FMPs and to ensure the long-term sustainability of insular stocks in the NWHI by preventing overfishing. To achieve these goals, a comprehensive insular research plan was developed and implemented. The plan should be considered a working document, subject to revision as necessitated by ongoing research and management developments. Objectives of the Laboratory's insular research program include the following:

- Monitor and assess the status of lobster and bottomfish stocks in the NWHI.
- Acquire understanding of fleet economics and industry standards.
- Conduct research as recommended by the Laboratory's lobster research team.

Major Research Activities

To support the research goals and objectives of the insular research program the Honolulu Laboratory conducts a suite of multidisciplinary research activities.

Lobster

Assess Population Status of Lobsters in the NWHI–Continue to conduct annual fishery-independent research cruises to collect population dynamics and relative abundance data to assess the status of lobster stocks in the NWHI. The research cruises also provide a platform for conducting experiments recommended by the lobster research team.

Reestimation of Biological and Population Parameters for Spiny Lobster in the NWHI–In accordance with recommendations from the lobster research team, and wide support from industry, a spiny lobster tagging program commenced in 1998. In addition to estimates of growth and movement, the tagging program will provide independent estimates of abundance, recruitment, mortality, catchability, and exploitation rate. The commercial fishery will provide the platform for recaptures during the 1999 fishing season, and at-sea biological technicians will screen the catch and record necessary biological information from recaptured lobsters. Initial tagging efforts were directed at Necker Island, and between September 1998 and June 1999 approximately 6,000 spiny lobsters were tagged and released.

Efforts are also underway to evaluate size at sexual maturity and fecundity for slipper lobster in the NWHI. This work is critical as only spiny lobster life history parameters are available to use as input to NWHI lobster stock assessment models and for the growing importance of slipper lobster to the commercial fishery.

Fishery Oceanography, Habitat, and Ecosystem–Joint studies with the Ecosystem and Environment Investigation will continue to advance our understanding of the physical and biological mechanisms contributing to recruitment variability in NWHI lobster populations. A recent study showed the utility of using altimetry data from the TOPEX-POSEIDON satellite to simulate transport dynamics of lobster larvae in the NWHI and may provide a new tool to investigate recruitment dynamics.

Essential Fish Habitat Requirements–The development of GIS applications using fishery-dependent (observer) and fishery-independent (*Townsend Cromwell*) lobster data was initiated in 1998. The objectives of this work are to model the spatial dynamics of NWHI lobster populations and the commercial fleet and to identify and delineate essential fish habitat (EFH) for lobsters (see Essential Fish Habitat section). Composite data sets for all *Townsend Cromwell* cruises from 1978 to 1997 have been constructed in Oracle and provide detailed location-referenced samples of species composition, age, size, sex, and reproductive condition. Data sets have also been constructed using observer data and provide location-referenced data detailing number of sets and catch rates by species, as well as samples of size and reproductive condition from commercial catches. These data are being assembled into a variety of GIS layers and used to determine the spatial structure of lobster populations in the NWHI. While work on identifying and delineating EFH for lobsters is continuing, it is hampered by a lack of fundamental data including bathymetry and habitat. These data will be required to advance our understanding of lobster habitat requirements and associations in the NWHI**.**

Issue Estimates of the Exploitable Population of Lobsters in the NWHI–Spatial management of the NWHI lobster trap fishery commenced in 1998 with the formation of four management areas--Necker Island, Maro Reef, Gardner Pinnacles, and all remaining banks. This approach was adopted in an effort to prevent local depletion of lobster stocks at Necker Island, Maro Reef, and Gardner Pinnacles and to spread out fishing effort in the NWHI, which in recent years has been limited to Necker Island and Maro Reef. To facilitate spatial management during the fishing season, estimates of the exploitable population of lobsters on July 1 (start of the fishing season) in the four management areas are required. The Laboratory will continue to provide these estimates using the guidelines provided by the Crustaceans FMP.

Status Determination Criteria and Control Rules–The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) contains a set of 10 National Standards for fishery conservation and management. National Standard 1 (Optimum Yield) of the MSFCMA states, "In general, Councils should adopt a precautionary approach to specification of OY." A common element in the application of the precautionary approach to fisheries management is the definition of status determination criteria or biological reference points and control rules. A control rule is a pre-agreed plan for making fishery management decisions (i.e., reduce fishing mortality) based on estimates of stock size relative to a defined set of status determination criteria (i.e., MSY). The Laboratory estimated several biological reference points, including some which were defined as overfishing status determination criteria under the MSFCMA. These reference points were incorporated into MSY and OY control rules and offered as suggestions for the Council's consideration (Fig. 1).

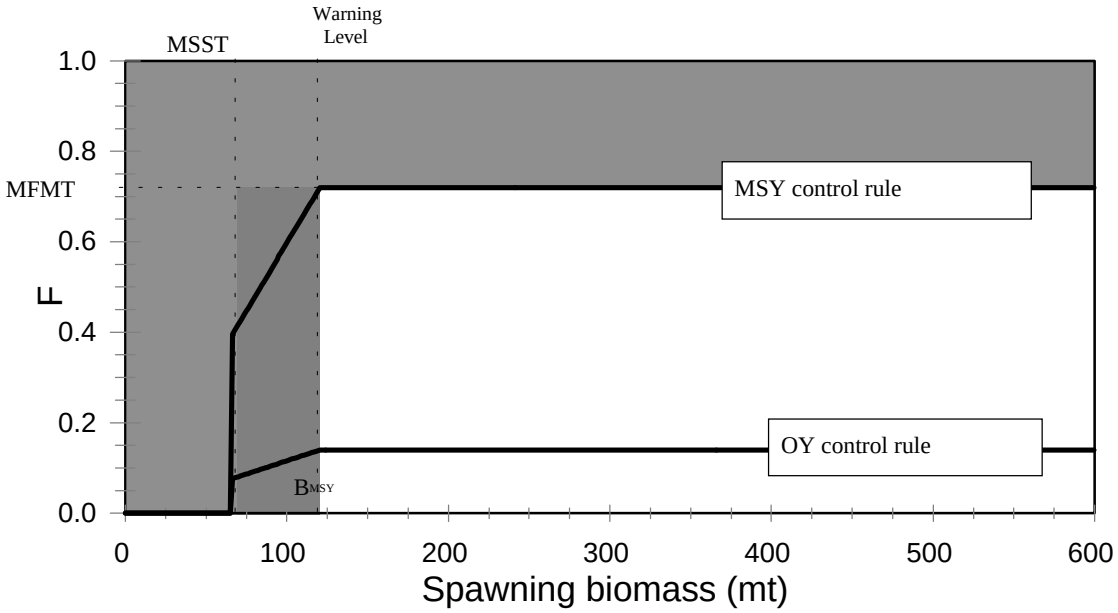


Figure 1. Proposed MSY and OY control rules for the NWHI lobster fishery (MFMT = maximum fishing mortality threshold, MSST = minimum stock size threshold, Bmsy = spawning biomass corresponding to MSY, F = fishing mortality).

Spatially Distinct Dynamic Population Models–The shift to a spatial management regime, change in recruitment pattern, and associated shift in species composition in the NWHI exemplifies the need for spatially distinct population models. Efforts are underway to develop spatially distinct population models and data collected by at-sea biological technicians during the 1997-98 commercial fishing seasons will facilitate model development.

Provide Scientific Support--Scientific and technical support to the NMFS Southwest Region and the Council will continue. Laboratory scientists also serve on the Crustaceans Plan Team.

Lobster Research Team--A research team composed of scientists from the Laboratory and the University of Hawaii and managers from the Council and NMFS Regional Office was established in 1995 to direct and oversee lobster research at the Laboratory. The role of the Lobster Research Team will continue.

Bottomfish

Assess Population Status of Bottomfish--Continue to analyze commercial fishery data to assess the status of bottomfish stocks in the Hawaiian Archipelago and summarize this information in the Hawaii module of the *Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region* annual report produced by the Council.

Submersible/ROV Research–The submersible *Pisces-V* and the Remotely Operated Vehicle (ROV) *RCV-150* (Hawaii Undersea Research Laboratory, University of Hawaii) were used to investigate non-lethal approaches for deepwater stock assessment using a variety of observational in situ techniques. Habitat data collected in this project will be useful for ongoing work with bottomfish EFH. This project is a cooperative effort with the State of Hawaii's Division of Aquatic Resources and the University of Hawaii and is anticipated to continue (see Essential Fish Habitat section).

Estimation of Parameters for Stock Assessment–Important biological parameters for bottomfish stock assessment continue to be improved. Specifically, improved estimates of the sizes at sexual maturity have been completed for two important species: ehu (*Etelis carbunculus*) and kalekale (*Pristipomoides sieboldii*).

Fishery Oceanography--Recruitment dynamics and larval mixing were investigated with advection-diffusion modeling using geostrophic current fields estimated from TOPEX/Poseidon satellite altimetry. These results were used in conjunction with genetic analyses to identify bottomfish stock structure.

Issue Fishery Management Advice–Assist NMFS Southwest Region and Council staff in determining optimal amount of fishing effort to allocate to the Mau Zone portion of the NWHI bottomfish fishery, which was recently converted to a limited entry fishery.

Provide Scientific Support--Scientific and technical support to the NMFS Southwest Region and Council will continue. Honolulu Laboratory scientists also chair and serve on the Bottomfish Plan Team. Significant support was provided to the NMFS Southwest Region and Council staff in 1998 and 1999 in determining the optimal amount of fishing effort to allocate to the Mau Zone regarding new MSFCMA definitions to stock status, and control rules for stock recovery. A control rule describes a variable over which management has some direct control as a function of some other variable related to the status of the stock. A preliminary CPUE-based approach to stock status determination and a template control rule based on a simple proportional reduction in the fishing mortality rate linearly related to decreases in the CPUE index have been presented to the Council for consideration.

ESSENTIAL FISH HABITAT

Background Information

With the passage into law of the 1996 Sustainable Fisheries Act (SFA) (Public Law 104-267), a new mandate to identify, conserve, and enhance essential fish habitat (EFH) for all fishery species managed under Federal fishery management plans was established. The SFA defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. For the purpose of interpreting the definition of EFH: 'waters' includes aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include aquatic areas historically used by fish where appropriate; 'substrate' includes sediment, hard bottom, structures underlying the waters, and associated biological communities; 'necessary' means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and 'spawning, breeding, feeding, or growth to maturity' covers a species' full life cycle." (EFH Interim Final Rule, 62 FR 66531).

The Honolulu Laboratory has in turn adopted an interdisciplinary approach of fishery biology, oceanography, and ecology and couples the use of GIS with satellite remote-sensing , in situ surveys, moored instruments, modeling, and commercial fishery data to describe and identify EFH.

Goals and Objectives

The goal of the EFH research at the Honolulu Laboratory is to collect and integrate information using the most advanced available technology to describe and identify EFH for the species managed under federal fishery management plans of concern to the central and western Pacific Ocean.

Major Research Activities

Pelagics

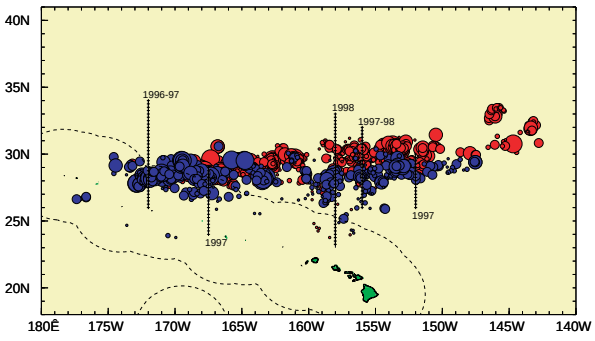


Figure 1. Swordfish monthly catch per set and research survey tracklines (cross-hatches = sampling resolution) during 1996-98.

Swordfish--Developing an understanding of swordfish habitat has been and continues to be a research focus for Honolulu Laboratory scientists. Assessment of swordfish distribution and abundance patterns based on fishery data together with environmental information gathered from shipboard surveys (in collaboration with University of Hawaii oceanographers) and satellite remote sensing has led to an oceanographic characterization of this habitat (Fig. 1).

During the peak winter-spring fishing season, swordfish occupy a region nominally referred to as the Subtropical Frontal Zone. Specifically, this region is bound by two distinct large scale convergent fronts:

the subtropical Winter Front to the south and the Subtropical Front to the north, each with unique biological implications.

The Winter Front is climatologically positioned between latitudes 28°N and 30°N during the months of January to April after which the front rapidly migrates northward with increasing insolation. The 20°C and 35.0 surface isotherm and isohaline, respectively, are usually seen embedded in the frontal gradients and are readily detectable by in situ and satellite sensors. Vertically, the thermocline shoals to a depth of about 70-80 m. Nutrients are transported into the euphotic zone, and production and standing stock of phytoplankton sharply increase at the subsurface chlorophyll maximum. Particularly noteworthy are (1) with regard to trophic transfer efficiency, the compositional makeup of the increased phytoplankton in response to the Winter Front which includes large diatoms (enhanced nutrient flux) and dinoflagellates as opposed to adjacent waters where very small picoplankton (photosynthesizing prokaryotes) dominate (Fig. 2) and (2) the absence of any surface expression of biological enhancement, as opposed to the observed chlorophyll expression north of the Subtropical Front. Shoaling of the thermocline is also believed to physically concentrate swordfish and their prey closer to the ocean surface and thus more vulnerable to surface longline gear.

To the north, the Subtropical Front (17°C surface isotherm, 34.8 isohaline) is typically positioned between latitudes 31°N and 33°N during January to April and also rapidly migrates northward thereafter. A surface chlorophyll front exhibiting a twofold increase in concentration is also normally associated with this front and is readily monitored by the SeaWiFS ocean color satellite (see Fishery Oceanography section). Dynamically, the increase in chlorophyll can be ascribed to the weakened vertical density structure and facilitated flux of nutrients into the surface waters.

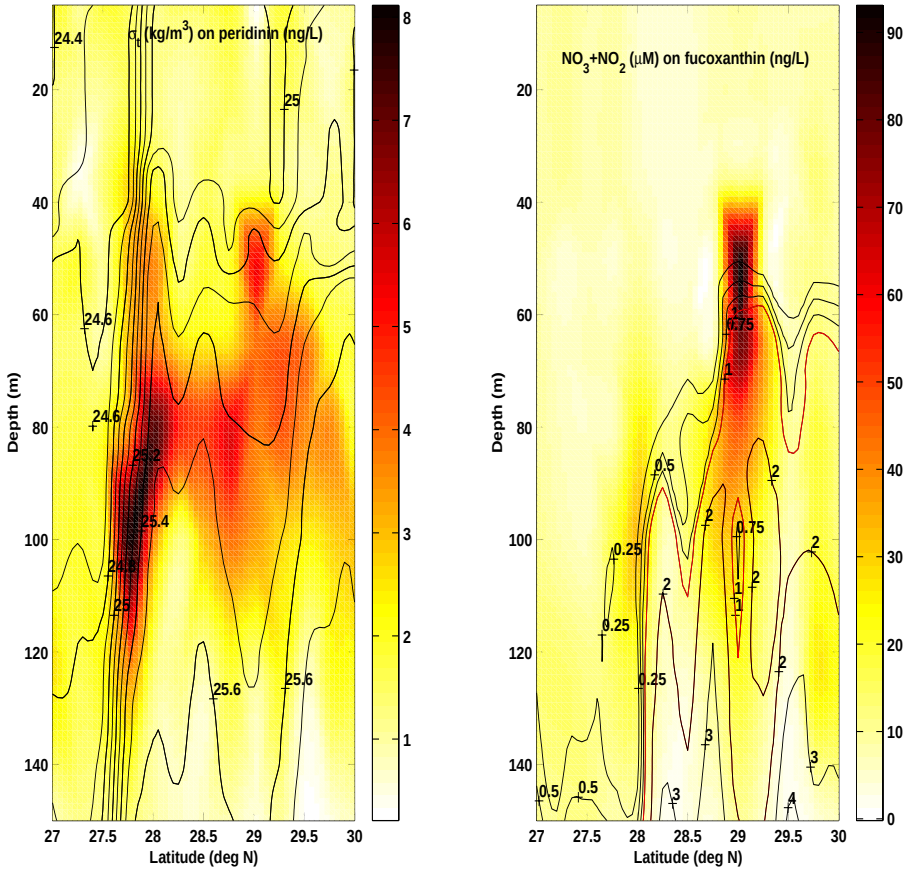
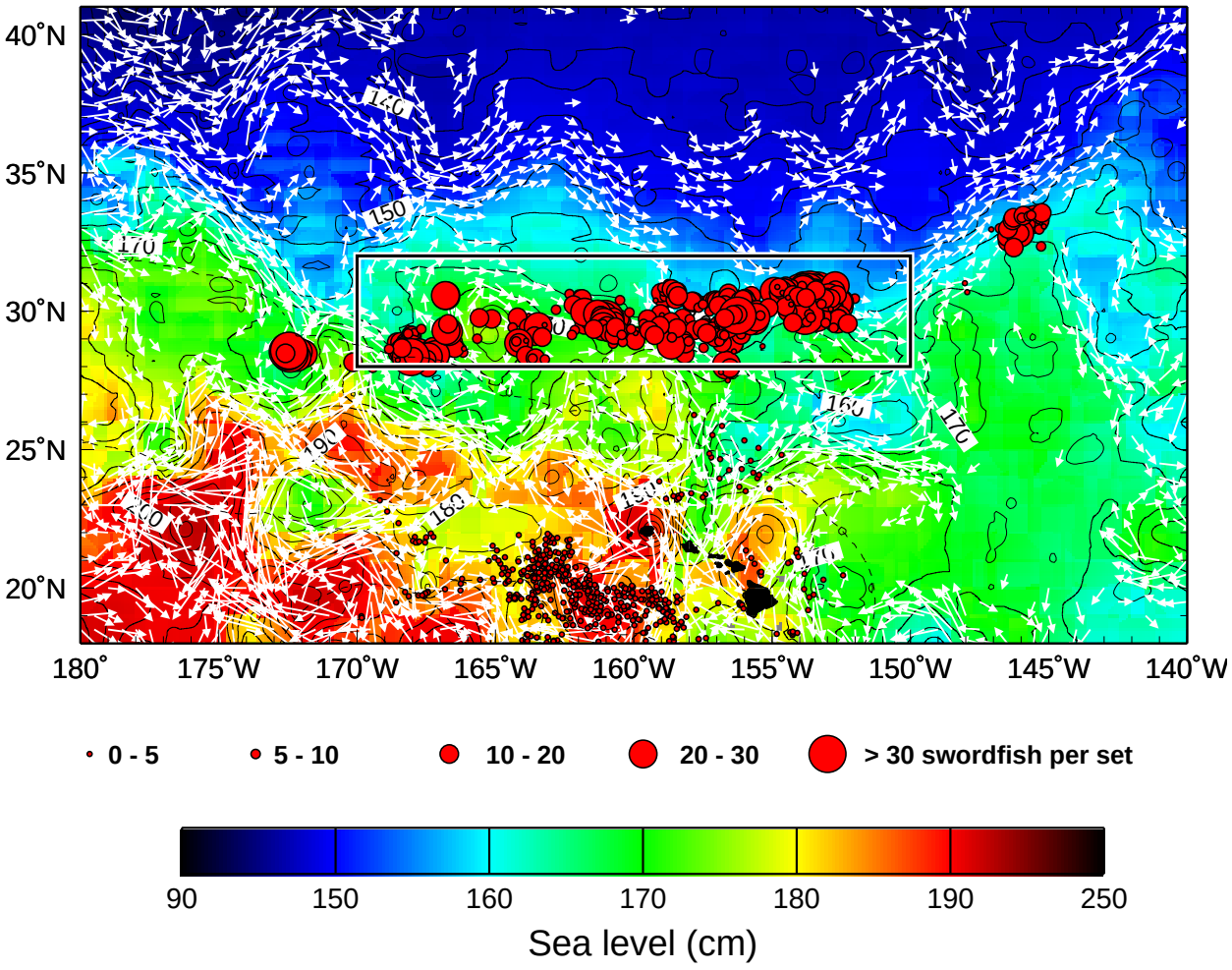


Figure 2. Depth distribution of (left) dinoflagellates (peridinin) as a function of density (σ_t) and (right) diatoms (fucoxanthin) responding to shoaling nutrients (nitrate+nitrite) through the Winter Front during April 1998. (Diagnostic pigments for phytoplankton classification are indicated in parentheses.)

The dynamical oceanography of the Subtropical Frontal Zone is captured in the measurement of sea level height from the Topex/Poseidon satellite altimeter, and a close relationship between the environment and fishery dynamics is readily observed (Fig. 3a,b). SLH measurements are used to develop a Subtropical Front environmental index (SFI) to help interpret fishery performance and CPUE; refinements to the SFI continue.

a. Sea level altimetry and geostrophic currents using Topex cycle 166 data, swordfish catch from 3/97



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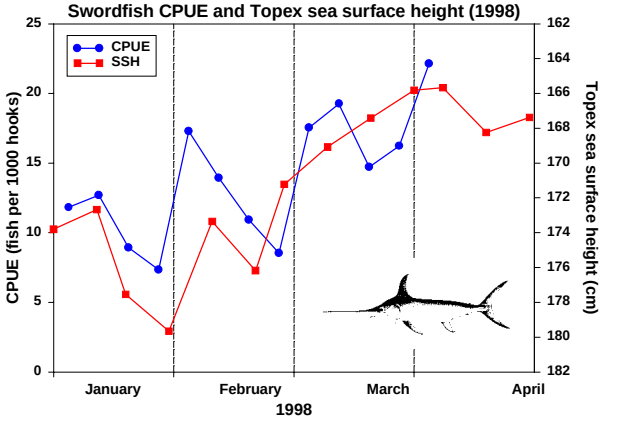


Figure 3. (a) The close relationship between the environment and fishery dynamics is presented as maps of sea level height and fish catches distribution. The ocean surface topography measured for 17-27 March 1997 and the commercial swordfish catches for March 1997. The numerous white arrows represent ocean currents ; the rectangular box represents the statistical area used to compute the sea level height index. (b) Sea level height from the Topex/Poseidon satellite altimeter has correlated well with commercial catch and effort patterns for swordfish in the fishing grounds north of Hawai.

Bigeye tuna--A new research initiative under the JIMAR PFRP is underway to study the role of the environment on bigeye tuna aggregation and vulnerability to fishing. The study will use the combined oceanographic information acquired from satellite (i.e., altimetry, temperature, ocean color), moored, and shipboard platforms together with commercial and research fishery data for the assessment. The mooring will be deployed about 185 km southwest of the island of Niihau at latitude 20°36.0'N, longitude 161°34.2'W (Fig. 4). This location was selected based on bigeye tuna CPUE, variability of CPUE, proximity to TOPEX altimetric satellite crossover paths, variability of oceanographic structure, and linkages to other PRFP projects. The BIGEYE mooring will describe the habitat of bigeye tuna by providing a time series of the vertical structure of temperature and velocity in the upper ocean. In anticipation of the scheduled December 1999 mooring deployment, an initial exploratory survey of the site composed of two 176 km - (95 nmi) long hydrographic/bathymetric transects (corresponding to the TOPEX satellite ascending and descending orbital passes) was conducted in May 1999. Topography at the targeted position was confirmed flat in 4,680 m (ca. 2,496 fathoms) of water with along-track information from a 12 kHz echosounder.

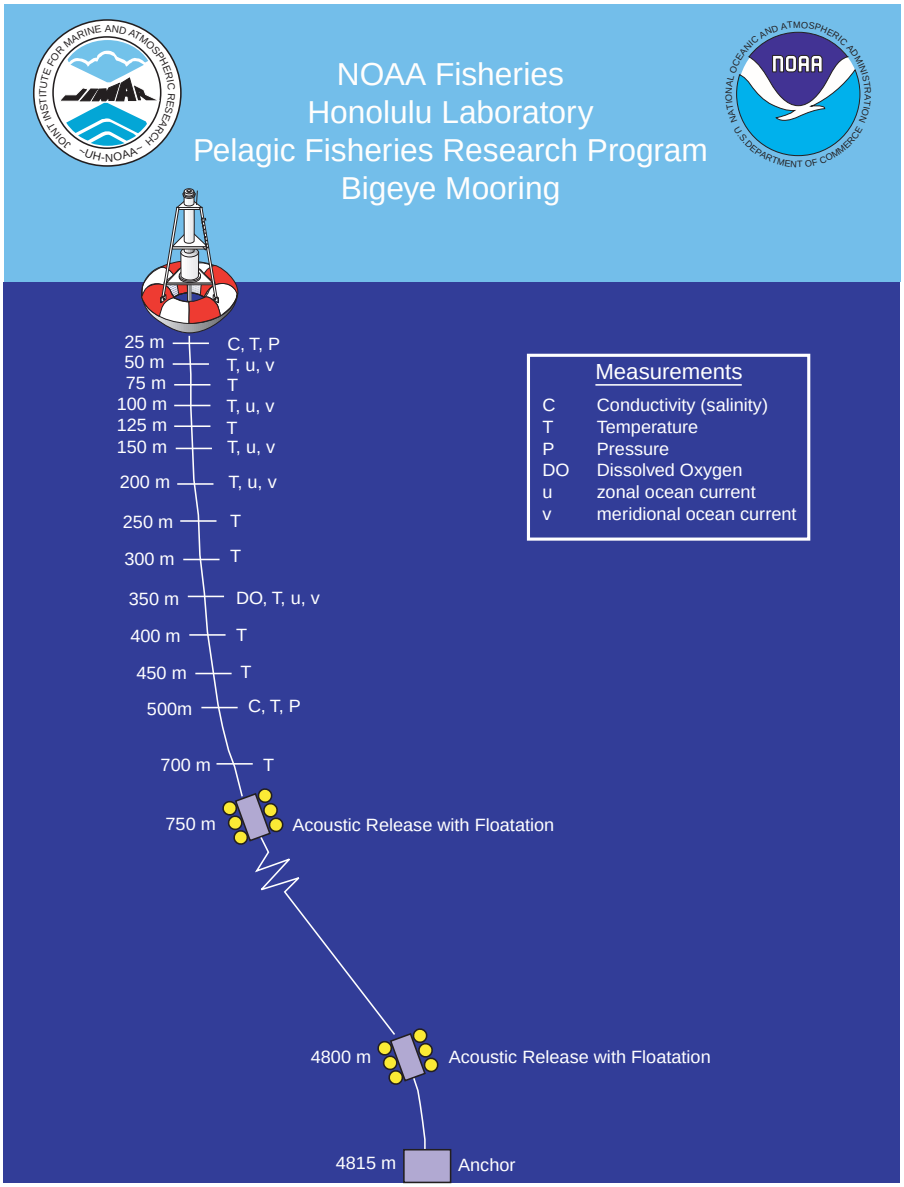


Figure 4. Schematic representation of the BIGEYE mooring design scheduled for deployment in December, 1999

Insular Resources

Lobster--The development of geographic information systems (GIS) applications using observer and *Townsend Cromwell* research lobster data continues. Composite data sets for all cruises from 1978 to 1997 have been constructed in Oracle to provide detailed location-referenced samples of species composition, age, size, sex and reproductive condition. Data sets have also been constructed using observer data from 1991 to 1997 to provide location-referenced data detailing number of sets and catch rates by species, as well as samples of size and reproductive condition from commercial catches. These data have been assembled into a variety of GIS layers that can be used to determine the geographical distribution of catch, sizes, sex, and reproductive condition. Work on identifying and delineating EFH for lobsters and other neritic species is ongoing but is hampered by a lack of fundamental data including bathymetry and substrate.

Bottomfish--Laboratory scientists are involved in two cooperative studies with the State of Hawaii Division of Aquatic Resources and the Hawaii Institute of Marine Biology using the Hawaii Undersea Research Laboratory (HURL) submersible *Pisces V*. One study will identify and characterize essential fish habitat, particularly nursery grounds, for onaga, ehu, and other deep water snapper species in the main Hawaiian Islands. The second study focused on the development of nonlethal methods for the assessment of overfished bottomfish resources. Dives on the former project identified a nursery ground utilized by both small ehu and onaga juveniles consisting of small, low carbonate (limestone) features scattered over an otherwise sandy bottom (Fig. 5).

Figure 5. Juvenile ehu, *Etelis carbunculus*, observed in situ occupying a low carbonate ledge in waters 300 m deep off Makapuu, Oahu.

Northwestern Hawaiian Islands Ecosystem

To better manage the fishery resources and protected species inhabiting the Northwestern Hawaiian Islands (NWHI), Honolulu Laboratory scientists are investigating trends in oceanographic conditions and variability along the entire Hawaiian Archipelago using a combination of data sets collected with shipboard acoustic Doppler current profiler (ADCP) and conductivity-temperature-depth (CTD) transects, moored oceanographic arrays, and satellite remote sensing.

Acoustic Doppler Current Profiler--An ADCP was installed aboard *Townsend Cromwell* in 1987 to collect data on ocean currents along each of the ship's cruise tracks. The ADCP measures ocean currents in the upper 250 meters of the ocean by transmitting acoustic signals into the water in four narrow beams at a frequency of 153 kHz. The sound reflects off particles and zooplankton drifting with the ocean currents back to transducers aboard the ship. The frequency of the returned signals is shifted slightly depending on whether the particles are moving toward or away from the ship's transducers. Based on the shifted frequencies of the four returned signals, profiles of the speed and direction of the ocean currents can be computed. With suitable processing, profiles of current velocities of the upper ocean can be computed along all of *Townsend Cromwell's* cruise tracks dating back to 1987. In 1998, Honolulu Laboratory oceanographers began processing the ADCP data archive from the present backward in time. To date, 59 cruises or 118 ADCP transects have been processed along the NWHI dating back to 1991. Since most of the cruise tracks along the NWHI are similar, these data provide

a time series, which oceanographers are using to examine the variability of the ocean currents and NWHI EFH over monthly, seasonal, interannual, and decadal time scales. Analyses of these data are ongoing, including analysis for the Hawaiian Ocean Mixing Experiment (see Fishery Oceanography section).

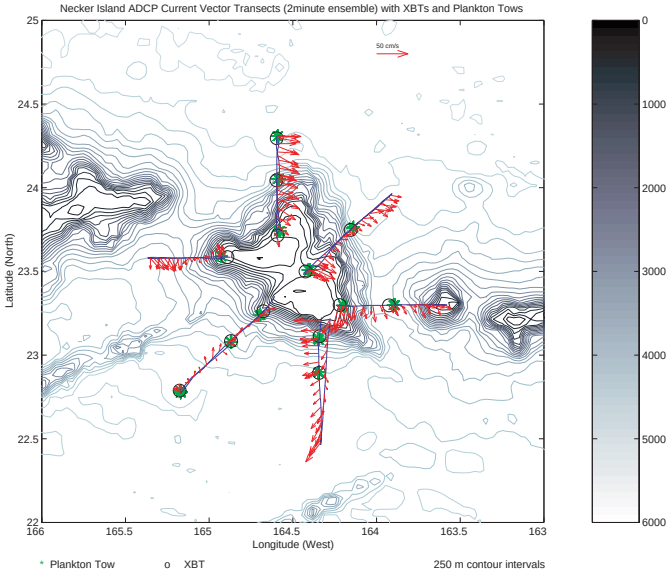


Figure 6. Acoustic Doppler current profiler (ADCP), expendable bathythermographs (XBT) and zooplankton trawl transects from NOAA Ship *Townsend Cromwell* around Necker Island in July 1998. Current velocity vectors for the depth layer between 25 m and 75 m are shown along the cruise track as red arrows. Locations of XBTs (black circles) and plankton trawls (green asterisks) are indicated. Bathymetric contours (in meters) are shaded according to the color bar on the right.

To better understand the ecosystem dynamics at two of the primary lobster fishing banks in the NWHI, Necker Island and Maro Reef, the annual lobster stock assessment and tagging cruises in 1998 and 1999 conducted nighttime ADCP transects radially outward from the banks (Fig. 6). In addition to ocean currents information, temperature with depth from expendable bathythermographs (XBT) and plankton tows using a 1-m diameter ring net with 505 and 200 micron mesh nets have been conducted. Honolulu Laboratory scientists are using these surveys to examine the spatial variability (horizontal and vertical) or patchiness of the zooplankton around these banks. Measurements of acoustic backscatter from the ADCP are also being used to estimate abundance and distribution of the zooplankton around the bank. The trawls are used to calibrate the backscatter data and determine the zooplankton species composition. All of these data are being used to improve understanding of lobster EFH.

Satellite Data--As discussed in the Fishery Oceanography and CoastWatch sections, satellite remote sensing data are being utilized to provide spatial and temporal coverage of the NWHI ecosystem. Figure 7 demonstrates the merging of several oceanographic data sets (shipboard ADCP, satellite-based AVHRR (sea surface temperature) and TOPEX/Poseidon (sea surface height), and bathymetry) to provide an enhanced description of the oceanographic processes along the NWHI at a particular time. Similarly, SeaWiFS ocean color and scatterometer winds can be merged to examine relationships and interactions between physical and biological processes.

In addition to using satellite remote sensing to examine oceanographic conditions over a large spatial area, Honolulu Laboratory and CoastWatch are using these data sets to examine temporal variability by generating time series at specific locations (Fig. 8). Time series are particularly valuable in examining seasonal, interannual, and even decadal variability of the NWHI ecosystem and the impacts of variability on EFH for lobster and bottomfish.

Brooks Bank Mooring--Honolulu Laboratory oceanographers, in collaboration with the University of Hawaii and NOAA's Pacific Marine Environmental Laboratory, deployed two subsurface oceanographic moorings in August 1998 on the flanks of Southeast Brooks Bank (lat. 24°00.3'N, long. 166°41.7'W) in 67 m and 80 m of water, respectively (Fig. 9). The first mooring is instrumented with an Aanderaa TR-7 thermistor string with temperature sensors every 5 m between depths of 20 and 70 m. In addition, there are six archival fish tags attached to the mooring to investigate the vertical dependence of the geo-locating algorithms. The second mooring is instrumented with an upward-looking RD

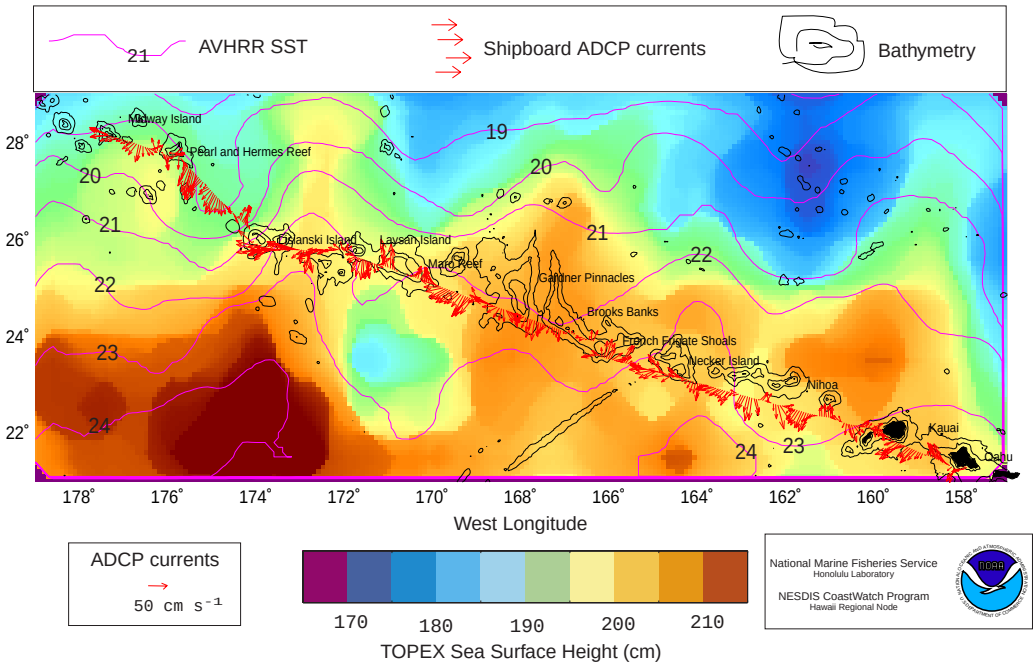


Figure 7. Shipboard and satellite-based data sets are merged to provide an enhanced description of the oceanographic processes along the NWHI during a cruise of the NOAA ship *Townsend Cromwell* in March 1996. Along track ADCP currents are depicted as red vectors (arrows), satellite AVHRR sea surface temperature contours are red contours with black numbering, TOPEX/Poseidon sea surface height is represented by false color shading, and black contours correspond to the bathymetry of the islands and banks of the NWHI

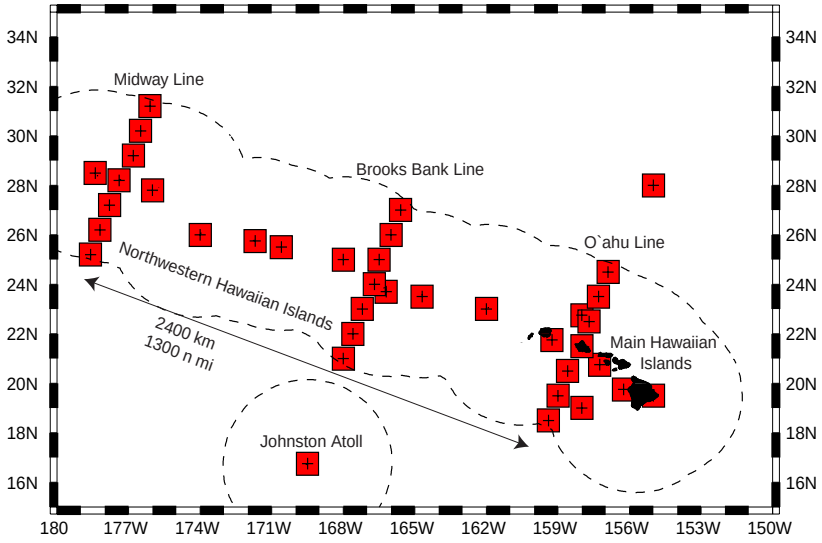


Figure 8. Standardized locations of time series satellite data sets generated by CoastWatch to monitor oceanographic processes in the NWHI ecosystem. Time series have been generated for surface winds, sea surface temperature, sea surface height, geostrophic currents estimated from sea surface height, ocean color, and significant wave height. The duration of these time series varies depending on the satellite sensors.

Instruments ADCP and a Seabird Electronics SBE26 wave and tide recorder. The ADCP is configured to measure ocean currents at 2 m vertical resolution between the depths of about 10 and 70 m.

These moorings, which are scheduled to be recovered in August 1999, will provide a time series of the vertical structure of oceanographic conditions and the amount of wave energy over the summit of a representative fishing bank along the NWHI. It is hypothesized that the strength of the currents and amount of wave energy reaching the summit are related to the types of flora and fauna which can inhabit the region. These banks provide the EFH for several important fishery resources (lobsters and bottomfish), as well as the foraging grounds for endangered Hawaiian monk seals. This time series will allow a detailed analysis of diurnal and seasonal variability of ocean conditions in critical habitats.

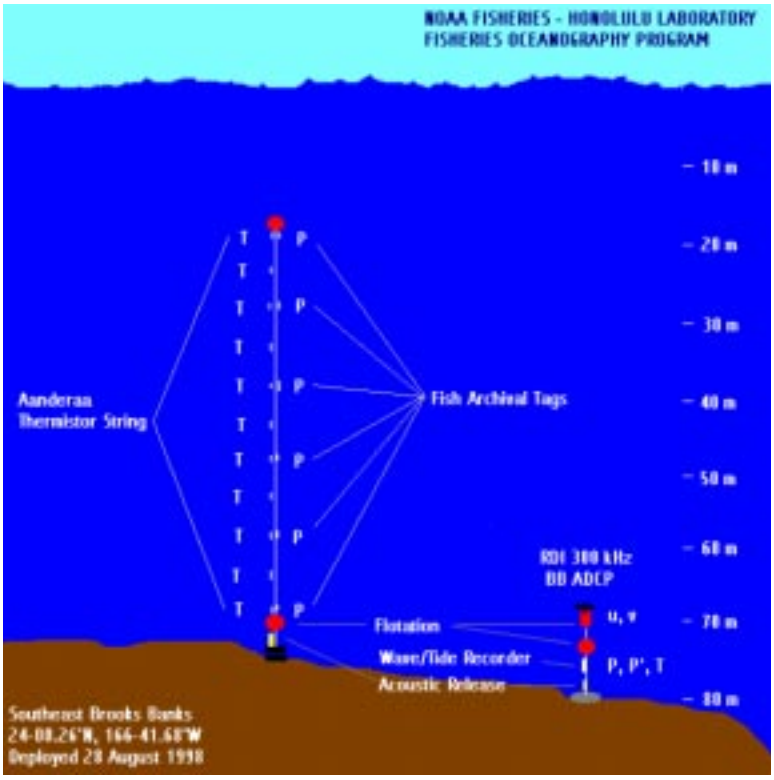


Figure 9. Schematic representation of two subsurface oceanographic moorings deployed in August 1998 on the flanks of Southeast Brooks Bank (lat. 24°00.3'N, long. 166°41.7'W) from the NOAA ship *Ka'imimoana*. The moorings are instrumented with an Aanderaa TR-7 thermistor string with temperature sensors every 5 m between depths of 20 and 70 m, five archival fish tags attached every 10 m, an upward-looking RD Instruments ADCP, and a Seabird Electronics SBE26 wave and tide recorder.

ASSESS, MONITOR, RESTORE, AND PROTECT CORAL REEF ECOSYSTEMS OF THE U.S. PACIFIC ISLANDS

Background Information

Coral reefs are among the oldest and most biologically diverse ecosystems on earth, harboring a richness of corals, reef invertebrates, fish and other fauna, and flora. By Executive Order 13089, the President established the U.S. Coral Reef Task Force to protect and restore valuable coral reefs. Although the Task Force is co-chaired by NOAA and the Department of the Interior, all federal agencies are directed to protect coral reef ecosystems to the extent feasible.

The U.S. Pacific Islands account for 94% of the nation's coral reefs (Fig. 1). The world's most biodiverse marine ecosystem, the Indo-Pacific, includes the Territories of Guam and American Samoa and the Commonwealth of the Northern Marianas Islands (CNMI) (Fig. 2). Although species richness is less, Hawaii accounts for 84% of U.S. coral reefs and contains the highest proportion of endemic marine species of any island group in the world. The remote Northwestern Hawaiian Islands (NWHI) and the Hawaiian Islands National Wildlife Refuge represent the largest 'no-take' coral reef reserve in the United States. The central equatorial Pacific Islands of Jarvis, Baker, Howland, Palmyra, Johnston, Wake, and Kingman Reef are mostly uninhabited and thought to be among the least damaged and least known coral reef ecosystems of the world. Unfortunately, lack of adequate assessment and monitoring of coral reef ecosystems of the U. S. Pacific Islands leaves scientists and managers uncertain of the condition and management needs of these ecosystems.

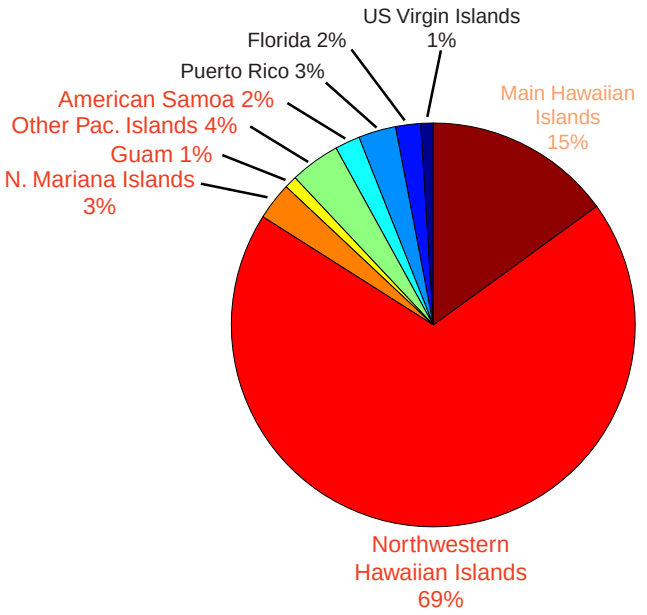


Figure 1. Percentage of U.S. coral reefs by area *(Miller and Crosby*, 1998)

Numerous instances of rapid change, including loss of species diversity and habitat, have been reported on coral reefs around the globe. The U.S. Coral Reef Task Force acknowledged that in 1998 coral reefs suffered the most extensive bleaching and subsequent mortality ever observed. Even reefs thought to be pristine, such as the NWHI, have suffered significant anthropogenic damage due to grounding of several thousand metric tons (t) of marine debris in the form of derelict fishing gear. This marine debris causes extensive physical damage to corals and essential fish habitat, entangles endangered and threatened species, and poses a threat to endemic reef flora and fauna by introducing invasive species.

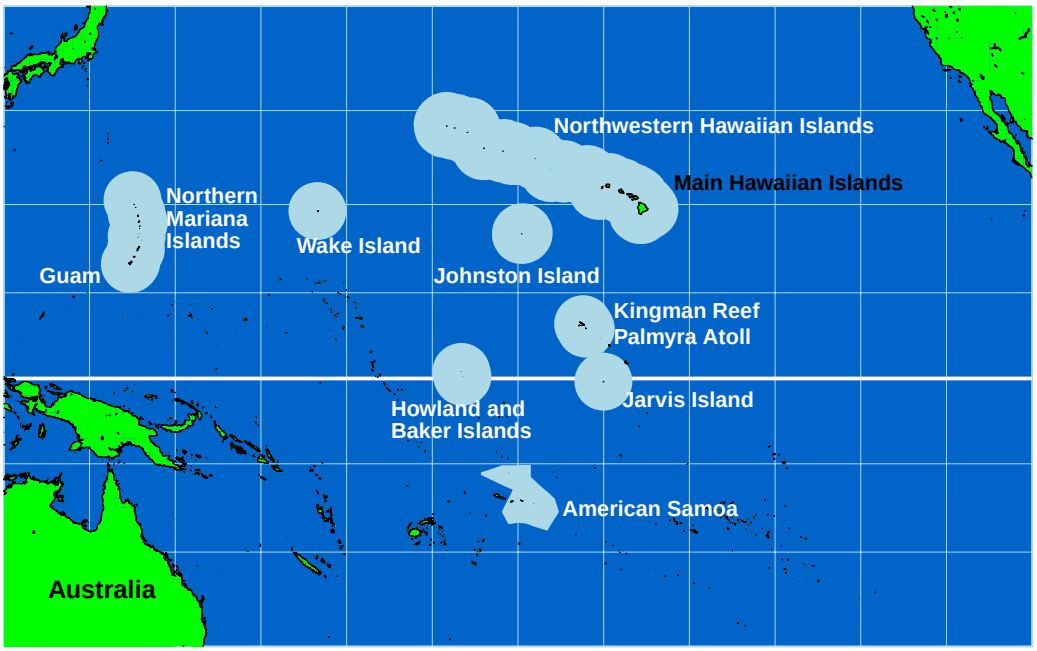


Figure 2. U.S. Pacific Islands and associated exclusive economic zones (EEZs).

Goals and Objectives

To address these concerns, Honolulu Laboratory has proposed a comprehensive multi-agency program to assess, monitor, restore, and protect coral reef ecosystems of the U.S. Pacific Islands. The goals of this program are to:

- Enhance coral reef fisheries management, including implementation of a Coral Reef Ecosystem Fishery Management Plan.
- Remove and prevent further accumulation of marine debris from coral reefs of the U.S. Pacific Islands.
- Improve management of existing marine protected areas (National Wildlife Refuges, National Marine Sanctuaries, and National Parks).
- Foster planning for additional marine protected areas.

The specific objectives of this program are to:

- Conduct thorough assessments of the present condition and health of the coral reef ecosystems of the U.S. Pacific Islands, including evaluations of the impacts of marine debris.
- Establish a program to monitor the health of coral reef ecosystems and essential fish habitat which will enable managers to evaluate anthropogenic and natural changes.
- Develop a cost-effective remote sensing capability to continue monitoring U.S. Pacific Islands coral reefs and essential fish habitat over the long term.
- Conduct mitigation efforts focused on removal of marine debris and limited reef restoration, as necessary to bring these ecosystems into their natural balance.

- Establish a multifaceted coral reef damage prevention program consisting of efforts to identify sources of derelict fishing gear by gear type, material, and construction; monitoring, tracking, and at-sea removal of derelict fishing gear using remote sensing; ocean circulation modeling; and enhanced public awareness and education efforts.

Major Research Activities

Assessment and Monitoring Program

In Situ Sampling--Annual in situ surveys of the health of the coral reef ecosystems of the U.S. Pacific Islands are proposed to provide a baseline for future comparisons and to provide remote sensing groundtruthing and calibration to allow continued long-term monitoring. The proposed surveys will be conducted in partnership with the U. S. Fish and Wildlife Service and the representative state and territorial governments as part of the National Coral Reef Monitoring Program. The surveys will utilize the most cost-effective combination of the Honolulu Laboratory's research vessel and chartered research vessels as the primary support platforms. These surveys will require about one month of field time for each of the four regions (NWHI, equatorial Pacific, American Samoa, and Guam/CNMI) per year. A reconnaissance survey of the equatorial Pacific region will begin in FY 2000, with other regional surveys beginning in FY 2001.

Major elements of the proposed in situ study design include the use of spatial replicates within reef subhabitats at representative banks/atolls. Multiple stations will be studied within either two or three major coral habitat types (exposed barrier reef, sheltered barrier reef, lagoonal patch reef). Analyses of our ability to detect real declines in the magnitude of our measured variables will be conducted to justify sampling effort. The experimental design will be sufficiently flexible to enable evaluations, for corals and other substrate-related variables, of both chronic (e.g., gradual, cumulative stresses due to widespread marine debris and global climate change) and acute impacts (e.g., ship groundings, oil spills, and localized marine debris). Key variables to be measured and evaluated include benthic structural heterogeneity, percentage cover of major substrates, percentage cover by major algal types and encrusting invertebrates, frequencies of encounter and densities of conspicuous macroinvertebrate, and frequencies and densities of fishes pooled into trophic levels. Analyses of fish data will emphasize apex predators (sharks, jacks, and groupers), which are recognized functional dominants of reef ecosystems worldwide. Living corals will be identified by taxa and grouped into major structural types. Specimens of algae and sessile invertebrates will be collected and used to document colonization of alien species and to expand chronicles of species presence-absence. Recording the prevalence of bleaching, tumors, and tissue necroses on corals will be emphasized in order to increase the probability of early detection of sublethal impacts. All in situ survey data will be recorded by digital camcorders at fixed-area stations. Sampling protocols will conform to internationally accepted standards of the National Coral Reef Monitoring Program.

The identity, magnitude, and location of marine debris encountered within defined larger regions of reef enclosing the fixed station areas will be digitally recorded as well. Collections of unknown taxa encountered on debris will be used to document possible occurrence of alien species. If alien species are identified, a comparative approach of species occurrence on debris and at stations within the same reef region will be used to examine the potential source of the alien colonists.

The proposed in situ surveys will include estimation of each of the parameters required to groundtruth and calibrate remote sensing data. An assessment of the underwater and water-leaving light fields will be measured at each station. Calibration efforts will include identifying as many habitat types and depths as possible.

Remote Sensing--Honolulu Laboratory proposes to utilize aircraft and satellite-based remote sensing technologies to expand the spatial coverage and temporal resolution of the in situ surveys. These efforts will be conducted in collaboration with other federal agencies, universities, and the private sector. Preliminary plans include early analysis of existing imagery to improve selection of in situ station locations. In collaboration with National Ocean Survey, reconnaissance surveys at select sites in the NWHI using panchromatic and hyperspectral or multispectral imaging sensors are proposed for FY 2000. These surveys will be followed by thorough aerial mapping of the NWHI in FY 2001. By using different spectral channels it is possible to identify specific spectral signatures of features otherwise indistinct in the visible range. Use of specific channels or a combination of channels will make it possible to discern between algae, corals, sand, and marine debris once the groundtruth work links the habitat to the respective spectral signatures.

The capabilities of satellite-based sensors to assess and monitor coral reef ecosystems are being investigated by Honolulu Laboratory scientists and our colleagues with CoastWatch and elsewhere.

Oceanographic and Environmental Monitoring--The Honolulu Laboratory scientists propose to establish an array of moored instruments to monitor key indicators of coral reef ecosystem health of the U.S. Pacific Islands. Some of the key properties linked to coral reef health and relatively easy to monitor are temperature, wind speed, wave energy, water clarity or siltation rate, and salinity. In addition, acoustic monitoring of the habitat is being investigated as an indicator of ecosystem health. These properties will be measured and recorded locally and then telemetered via satellite to the Honolulu Laboratory for dissemination on a web site to enable early warning and monitoring of reef conditions. Oceanographic/environmental monitoring will improve our ability to distinguish between anthropogenic and natural causes of change.

Remotely sensed observations of sea surface temperature (AVHRR), sea surface height (altimeter), surface winds (scatterometer), ocean color (SeaWiFS), and planned follow-on satellite sensors will be used to examine the larger scale oceanographic and atmospheric conditions surrounding these coral reef ecosystems.

Coral Reef Restoration Program

Honolulu Laboratory proposes a Coral Reef Restoration Program to mitigate some of the known and yet-to-be-determined sources of degradation to coral reefs of the U.S. Pacific Islands. Initial efforts will focus on expanding the existing Honolulu Laboratory-led multi-agency cooperative efforts to remove several thousand t of marine debris from the coral reefs and beaches of the NWHI. These efforts were begun in the early 1980s to reduce mortality and injury to endangered Hawaiian monks seals, which have been observed entangled in these nets an average of 15 times annually. In 1996, these efforts were expanded to include the coral reef habitats, as opposed to beach surveys only. In addition to monk seal entanglements, these surveys revealed extensive damage to coral reefs and essential fish habitat by marine debris. Removal efforts were greatly facilitated in 1998 by partnering with the U.S. Coast Guard, U.S. Navy, U.S. Fish and Wildlife Service, Office of NOAA Corps Operations, University of Hawaii Sea Grant Program, Hawaii Coastal Zone Management Program, University of Alaska Marine Advisory Program, City and County of Honolulu, University of Hawaii, Center for Marine Conservation, Hawaii Wildlife Fund, Natural Resources Consultants, Browning Ferris, Inc. (BFI), and NET Systems. These cooperative efforts have removed about 10 t of marine debris from NWHI coral reefs. Future activities

will continue to focus on multi-agency cooperation from all sectors.

In October 1999, Honolulu Laboratory will lead another multi-agency cooperative marine debris removal effort to the shallow reefs of Lisianski Island and Neva Shoal, where data indicate the highest incidence of monk seal entanglements. Two 6-8-month marine debris removal expeditions are proposed for FY 2001 and FY 2002. Utilizing a larger, helicopter-equipped vessel dedicated to debris removal, these expeditions are projected to remove marine debris from 75% to 80% of the reef habitat of the NWHI. These efforts will focus on prioritizing regions and cleanup strategies to maximize efficiencies and benefits to overall ecosystem health.

As part of the coral reef assessment and monitoring activities of the other U.S. Pacific Islands, marine debris surveys and removal activities will be conducted. Whenever possible, removal activities will continue in partnership with other federal, state, territorial, and local agencies, as well as many non-governmental organizations. These reef restoration efforts will also focus on educating and assisting the resident populations, as necessary, to improve coral reef stewardship, conservation, and protection.

The success of the marine debris removal efforts will be assessed by the ongoing monitoring in terms of overall coral reef ecosystem health. In some instances, monitoring may show that additional restoration efforts will be needed to return the reefs to their natural ecological balance. Additional efforts could involve coral cultivation and transplantation methods presently being developed and utilized in the Florida Keys and elsewhere.

Coral Reef Protection Program

Honolulu Laboratory has proposed a plan to protect U.S. Pacific Island Coral Reef Ecosystems consisting of three primary components: 1) identification of derelict fishing gear and its source, 2) remote sensing to track and interdict marine debris at sea before it damages coral reef ecosystems and, perhaps most importantly, 3) public awareness and education. Each of these preventative efforts is aimed at reducing the source of marine debris available to damage coral reef ecosystems.

Efforts are underway to identify the sources of derelict fishing gear based on gear types, materials, and construction methods. These identification efforts will be increased, and national and international efforts must be taken to characterize fishing gear so that the sources of marine debris can be positively identified.

A significant amount of marine debris continually circulates around the ocean gyres. Eventually, this debris grounds on coral reefs and disrupts the ecological balance of the reef community. Figure 3 demonstrates that oceanic convergence driven by surface winds works to concentrate marine debris in the subtropical front region north of the Hawaiian Archipelago, particularly during the winter months. These convergence zones can be remotely observed using a combination of several satellite-based sensors (scatterometer [winds], AVHRR [temperature], SeaWiFS (ocean color), TOPEX/Poseidon [sea surface height]) to guide aerial and shipboard reconnaissance for removal of the debris at sea. This information will also be used to help identify source regions.

Finally, recent efforts to educate the public about the marine debris problem will be continued and expanded. Efforts will focus on educating the commercial fishing and maritime industries about the damage to coral reef ecosystems by marine debris and on efforts to minimize future damage by reducing or eliminating the source. All aspects of this plan must involve collaboration with other Pacific Rim countries to ensure the long-term success of coral reef ecosystem conservation and protection in the Pacific Ocean.

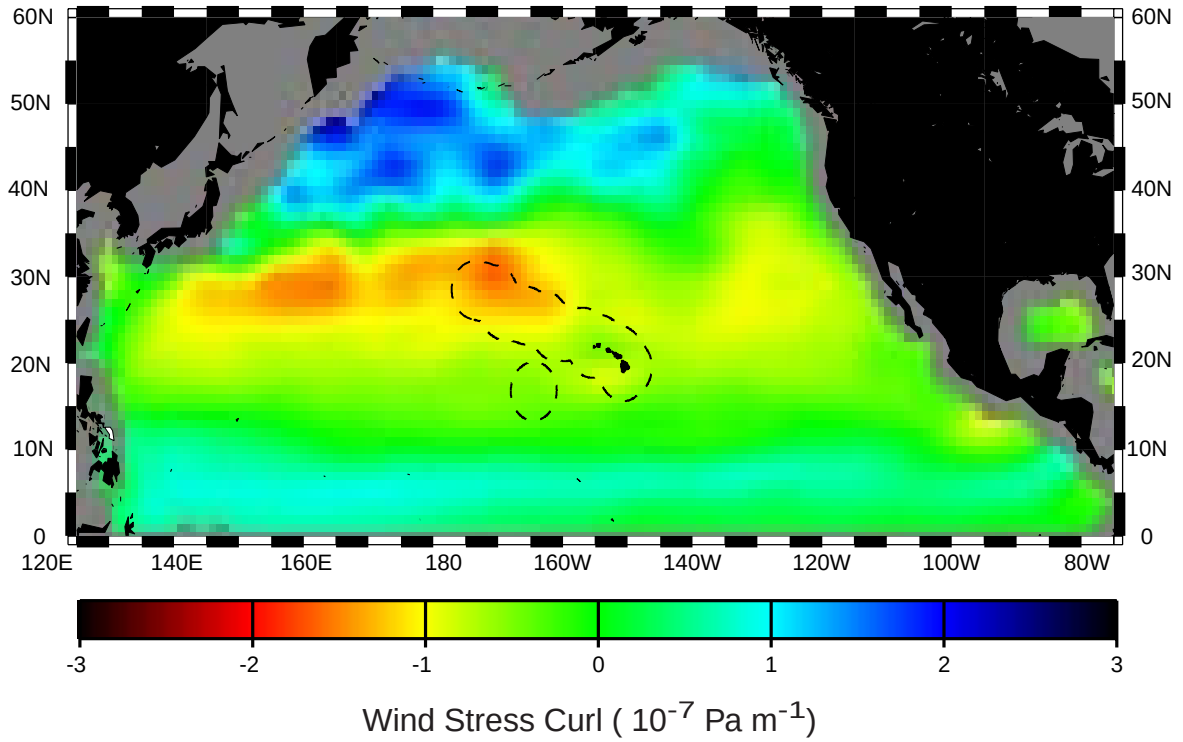


Figure 3. Mean winter wind stress curl from satellite measurements over the period 1993-98. Negative wind stress curl represents oceanic convergence and likely concentration or accumulation of marine debris.

International Workshop on Derelict Fishing Gear, Vessels, and Operational Waste: Sources, Impacts, Mitigation, and Prevention

Honolulu Laboratory will be leading an International Workshop on Derelict Fishing Gear, Vessels, and Operational Waste: Sources, Impacts, Mitigation, and Prevention in collaboration with our multi-agency partners in Marine Debris Removal (listed above). The goal of the workshop, scheduled for June 26-30, 2000 at the Turtle Bay Hilton, is to convene international experts to evaluate the sources and ecological impacts of derelict fishing gear on coral reef and other marine ecosystems, with emphasis on the Pacific Ocean, and to recommend mitigation and prevention strategies based on environmental, economic, and political realities.

The specific objectives of the workshop are to:

- Review impacts of derelict fishing gear (including grounded vessels and other maritime sources of marine debris) on coral reef and other marine ecosystems (including protected species, essential fish habitat, and introduction of alien species).

- Assess and develop mitigation and prevention techniques to protect coral reef and other marine ecosystems.

- Establish national and international partnerships with scientists, economists, fishermen, maritime industries, environmentalists, and policy makers to address the derelict fishing gear and vessel grounding problems.

- Increase national and international public awareness of derelict fishing gear by recommending political and educational strategies that will establish a stronger stewardship ethic for all stakeholders.

- Assign working groups to follow through on workshop recommendations to prevent future threats.

Proposed Budget and Staffing

The NOAA Recover Protected Species (RPS), Sustain Healthy Coasts (SHC), and Build Sustainable Fisheries (BSF) Strategic Planing Teams have proposed a $10 million joint Coral Reef Ecosystem Initiative for FY 2001. Of this amount, Honolulu Laboratory's proposal to Assess, Monitor, Restore, and Protect Pacific Coral Reefs is targeted to receive $3.9 million, with $3 million specified for management-related activities including marine debris removal and restoration and $0.9 million specified for monitoring of coral reefs of the U.S. Pacific Islands. Sustained funding at this level of funding will be required to meet the ambitious goals of this program. During the outyears, an increased proportion of the funding will be aimed at assessment and monitoring activities. Most of the proposed funding covers the costs for vessel charters and personnel. Personnel requirements include six FTEs, four of which are existing Laboratory employees, and a large contingent of full and part-time JIMAR hires. Most of the JIMAR hires will be employed for the extensive marine debris removal activities.

HAWAIIAN MONK SEAL RESEARCH

Background Information

The Hawaiian monk seal is the only endangered marine mammal located entirely within U.S. waters, and its future is in grave jeopardy. Current abundance is ca. 1,300 to 1,400 animals. Beach counts (a historical index of abundance) have declined by 60% since the late 1950s, and 4% to 5% annually from 1985 to 1993 (Fig. 1).

Counts stabilized during 1993 to 1998, apparently in part due to actions taken to recover the species. However, there is concern that the decline in population may continue in the near future because of high juvenile mortality and low reproductive recruitment at French Frigate Shoals (FFS), the largest of the six main reproductive subpopulations (Fig. 2). Conceivably, the Hawaiian monk seal could be on the verge of extinction in 20 years.

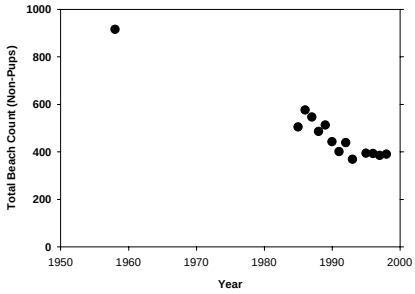
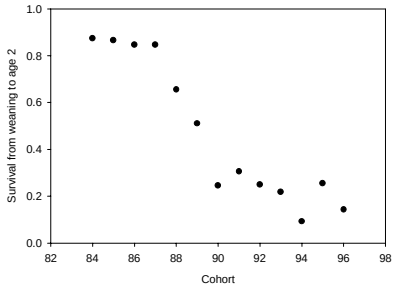


Fig. 1. Decline in non-pup beach counts of Hawaiian monk seals at the six main subpopulations in the Northwest Hawaiian Islands, 1958-present.

In 1976, the species was designated as depleted under the Marine Mammal Protection Act and listed as endangered under the Endangered Species Act. Although the population remains at critically low numbers, the recent stabilization of population trends has been facilitated by mitigation efforts to enhance survival of females and by natural recruitment.

Elements influencing population growth vary by reproductive site. Naturally occurring factors that have or may impede population growth include disease, male aggression toward adult females and immature seals of both sexes, habitat degradation due to storms and high seas, and reduced prey availability due to natural variations in oceanic productivity. Anthropogenic factors that have limited population growth include entanglement in marine debris and human disturbance.

The Hawaiian Monk Seal Program has identified five critical projects involving recovery and conservation research and implementation measures used to recover the endangered Hawaiian monk seal. Two of these projects, population assessment and translocation of weaned monk seal pups, were initiated in 1983 and 1984, respectively, and have greatly contributed to the recovery of this species. Work involving the Translocation of Weaned Monk Seal Pups experienced a temporary hiatus from 1995 to 1998 when 12 captive seals in rehabilitation were determined unfit for release into the wild because of an eye ailment, and funds for translocation were reprogrammed for their care and husbandry. Other projects that have been identified as important for the recovery and



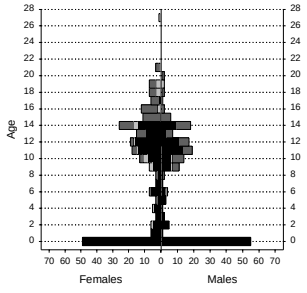


Figure 2. a) Survival of Hawaiian monk seals from weaning to age-2 at French Frigate Shoals. b) Age composition at French Frigate Shoals in 1998.

conservation of this species include removal of marine debris on coral reefs, Hawaiian monk seal foraging ecology**,** and health assessment and disease status of wild Hawaiian monk seals. The need to implement all of these high priority projects is consistent with recommendations of the Hawaiian Monk Seal Recovery Team, the Marine Mammal Commission, the Marine Mammal Research Program (Honolulu Laboratory), and the Captive Care and Recovery Review Panel of independent specialists.

Goal and Objectives

The primary goal of this program is to enhance recovery of the critically endangered Hawaiian monk seal population.

Our major objectives are the following:

- Monitor and assess the six main monk seal reproductive subpopulations on the Northwestern Hawaiian Islands.
- Study the ecology, biology, and natural history of the Hawaiian monk seal.
- Investigate and mitigate factors impeding the recovery of this critically endangered species.
- Conduct community outreach and education of the public on research and action to recover the species.

Major Research Activities

Population Assessment and Monitoring

Population assessment and monitoring is a critical and ongoing project which occurs at all main reproductive locations (French Frigate Shoals, Laysan and Lisianski Islands, Pearl and Hermes Reef (Fig. 3), and Midway and Kure Atolls). In addition to assessing population abundance, trends, survival, and age/sex composition, researchers also document and mitigate, whenever possible, factors which may be limiting population growth (e.g., entanglement in marine debris). This effort is essential for identifying sites where population growth is limited, detecting impediments to recovery, and assessing consequences of mitigation efforts to enhance the growth of this critically endangered species. The information from this work is also required for population modeling to predict the outcome of possible management strategies designed to enhance the recovery of the species.

Assessment activities were initiated in the early 1980s, and progress to date has been extensive with many successes. Accomplishments in FY 1999 include deployment of field camps at all six major reproductive sites, removal of entangling marine debris from all major pupping and haul-out sites and disentanglement of all seals caught in marine debris, a draft summary of the 1998 Hawaiian monk seal population monitoring activities for the Hawaiian monk seal recovery team meeting, and completion of an updated Hawaiian monk seal field manual. In FY 1998 a record number of 246 monk seal pups were born on the NWHI, surpassing all previous counts since the program began in 1982. Preliminary survey data indicates that pup production may be at least as high in FY 1999.

Fig. 3. Pearl and Hermes field camp.

In spite of important progress during the previous decade, the status of this endangered species remains extremely grave, and the comprehensive and consistent long-term research and recovery efforts must be maintained. The severity of past problems (both natural and anthropogenic) that have caused decline or impeded recovery, the potential for new and unforeseen problems, and the inherently slow recovery rate of this species strongly argue that recovery of the Hawaiian monk seal will require continued long-term, comprehensive commitment by the National Marine Fisheries Service.

Plans for FY 2000 will include an annual assessment of each reproductive population by determining abundance, age and sex composition, survival rates, natality rates, migration, sources of mortality, health and disease, reproduction, growth and condition of seals, behavior, haul-out patterns, migration, fisheries interactions, entanglement in marine debris, and prey species. A summary of each field season will be reported in a draft NOAA Technical Memorandum which will be intensively reviewed at the annual Recovery Team meeting. Also, an evaluation of the effectiveness of various Recovery and Conservation Measures (e.g., translocation of weaned pups from French Frigate Shoals, normalizing sex ratio at Laysan Island to reduce mobbing), will be determined at each appropriate reproductive location.

Foraging Ecology

Efforts to enhance the recovery of Hawaiian monk seals require an understanding of factors influencing their foraging success. Recent studies have indicated that natural variation in the oceanic environment and marine productivity around the Northwestern Hawaiian Islands (NWHI) have likely reduced the availability of monk seal prey species at some locations. However, the level of interaction between monk seals and commercial fisheries remains poorly understood. These interactions could include direct interaction with gear of various fisheries (lobster trapping, bottomfish handline, pelagic longline, and, potentially, precious coral ROVs) as well as indirect interactions through reduced prey availability of the target species. Concern over the potential for fishery interactions helped to promote designation of “critical habitat” for the monk seal in 1986. Also, lobster fishing was prohibited in waters less than 10 fm around all NWHI. In 1988, Maro Reef and waters around major haul-out sites out to 20 fm were added to existing critical habitat. In 1991, additional protection of monk seal habitat was provided by the establishment of a Protected Species Zone, which prohibited longline fishing within 50 nmi around the NWHI and corridors between islands.

Information is needed to validate the 20-fm critical habitat designation and the 50-nmi Protected Species Zone. Maintaining these boundaries requires definition of habitat use by monk seals of all age and sex categories. This will also be critical for Section 7 consultations concerning precious coral fisheries in the NWHI. The Marine Mammal Commission (MMC) raised concerns about potential interactions between monk seals and the NWHI lobster fishery. The MMC suggested that the take of lobster and associated bycatch (e.g., octopus) has reduced monk seal prey resources, especially for juvenile seals at FFS. The validity of this speculation cannot be verified on the basis of existing data. Thus, important knowledge must be gained to evaluate the significance of lobster in the monk seal's diet and the impact of the lobster fishery on the benthic reef ecosystem.

Fig. 4. Hawaiian monk seal with "critter-cam" recorder.

Recent studies investigating the foraging range of monk seals at two of the six main subpopulations, French Frigate Shoals (FFS) and Pearl and Hermes Reef (PHR) tend to support the food limitation hypothesis for the FFS subpopulation. Differences in foraging ranges of seals from these sites were found. FFS seals foraged over a much greater area than the seals at PHR, perhaps due to lower prey availability. No data are available from the remaining sites, and no information exists on the foraging habits of weaned pups, which are likely most vulnerable to food limitation. Recent studies have also identified a different potential interaction between the commercial bottomfish fisheries in the NWHI and the monk seal. Satellite-linked dive recorders and "critter-cam" video (recorders carried by seals, Fig. 4) have shown that monk seals commonly dive to depths of 10-200 m and forage on commercially valuable fish. It is possible that bottomfish (snapper, groupers, and jacks) are more important in the monk seal's diet than originally thought, thus additional information is needed to address this concern.

Continued support in development of the "critter-cam" and related technologies, simultaneous with data collection from these devices, is required to realize the potential of this technology. Additionally, food availability is a likely factor influencing early survival, but little is known about the feeding habits of juveniles. Knowledge of key prey species and characterization of foraging habitat, especially during the transition to nutritional self-sufficiency, are essential for identifying and mitigating factors that may be compromising juvenile survival. Digital video technology has been incorporated into smaller camera packages this year that will enable the first instrumentation of juvenile seals to begin. Juvenile seals are the most impacted segment of the FFS population and identifying the forage habitat of this age class represents the focus of future instrument studies.

HURL submersibles *(Pisces V* and *RC-150)* were used at FFS to survey the ocean floor at two sites where previous satellite tagging studies showed seals focused on deep dive activity. Both of the sites were found to support precious coral beds. Submarine surveys at other sites found no precious coral indicating monk seals may specifically target them on deep dives. Of particular concern is the largest of the precious corals, gold coral, which many fish use as shelter. Available data suggest that gold coral is slow growing (50-100 years of age) and has low or infrequent recruitment. Harvest of the gold coral colonies could diminish the seals' access to prey, and concern has prompted modification of harvest regulations to protect the endangered seal's forage habitat. Zero quotas have been proposed for gold coral at the beds around FFS. Non-selective harvest methods such as dredging with coral nets will be prohibited to protect monk seal forage grounds and ensure preservation of essential fish habitat.

Since 1992, annual surveys of reef fish abundance and size structure have been conducted on the reefs of FFS and Midway atolls. In 1998 the surveys at FFS were extended to deeper slopes (60 m) to include fish communities in habitat where seals are known to focus their feeding (Fig. 5). In the future, additional deep slope data will be collected if fish populations at the shallow stations indicate an increase in production.

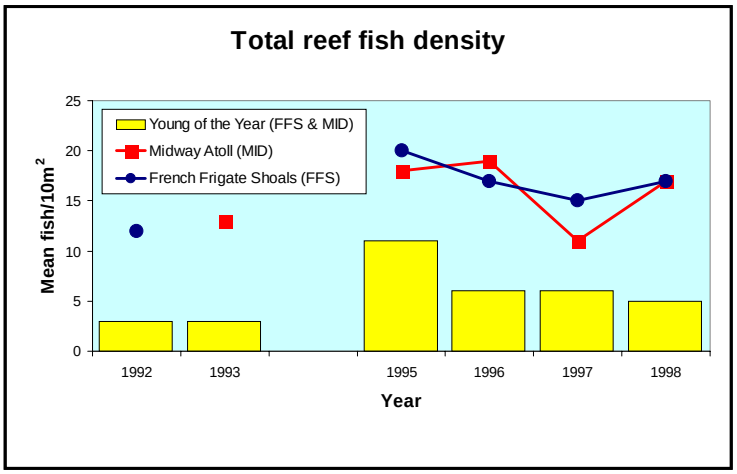


Fig. 5. Density of reef fish at Midway Atoll and French Frigate Shoals, 1992-98.

Plans for FY 2000 will involve characterization of habitat use, prey selection, and prey availability/abundance. This research is vital for identifying and evaluating future recovery efforts and will focus on issues stemming from concerns associated with possible interactions between commercial fisheries and Hawaiian monk seals. Habitat use will be characterized through the use of VHF transmitters, time/depth recorders, critter-cams, and satellite telemetry. Prey consumption will be assessed through the analysis of scats and spews and using a promising technique, fatty acid analysis, to assess the relative importance of lobster in the diet. A pilot study in 1998 based upon a limited sampling of potential prey species and monk seal blubber biopsies indicated that fatty acid signatures differ among prey species and that lobster may be identified with high probability using this method. More samples were collected in 1999, and a greatly expanded fatty acid research project will continue into the year 2000. Prey abundance will be assessed with ongoing reef fish surveys, and the results will be examined for potential relationships to environmental changes in the marine ecosystem.

Health and Disease Assessments

The influence of disease on monk seal population trends is poorly understood. Disease processes may be important determinants of population trends through long-term low levels of mortality, or through episodic die-offs. The mass mortality of monk seals that occurred at Laysan Island in 1978 may have been due to a disease process. Similarly, disease may be contributing to the high juvenile mortality occurring at FFS since 1988. In addition, the potential for disease transmission has been an important concern in management activities involving translocation of seals between reproductive sites. It is possible that disease could have contributed to the extensive loss of seals translocated to Midway Atoll during 1992-93.

Plans to bolster population growth by translocation or modified “head-start” programs for monk seals will need to address the incidence of disease in the subpopulations involved. Preliminary health and disease surveys for a translocation project indicated that low serum antibody titers to morbillivirus were present in 3 of 51 seals examined at FFS, but seals at other sites were all negative. These results suggested that the population may be at serious risk because the same type of virus has been responsible for other massive marine mammal die-offs in other parts of the world. However, because of the low antibody titers and apparently limited potential exposure, an additional investigation was required to fully evaluate the threat of this potential pathogen. From January 13 to February 5, 1999, a team of researchers returned to FFS to validate exposure of the population to a morbillivirus. They evaluated 47 seals, 30 of which had not been examined during the previous survey. Two of the three

seals with low antibody titers for morbillivirus from the first survey, were also sampled. All serum antibody titers were negative from the second survey indicating that the monk seal population at FFS had not been exposed to a morbillivirus and was not imminently at risk of experiencing a mass die-off (Table 1).

Table 1. Serological test results from Hawaiian monk seals from French Frigate Shoals, Pearl and Hermes Reef, and Midway Atoll, 1997-98. The ratio of seropositive seals to total number tested is shown for all disease agents investigated at multiple diagnostic laboratories (IDDEX = IDDEX Veterinary Services, Sacramento, CA. OADDL = Oklahoma Animal Disease Diagnostic Laboratory, Oklahoma State University, Stillwater, OK. FSBL = Federal/State Brucellosis Laboratory, Oklahoma City, OK. LCS = Laboratory for Calicivirus Studies, Oregon State University, Corvallis, OR. NVSL = U.S. Department of Agriculture, National Veterinary Services Laboratory, Ames, IA. ARS = U.S. Department of Agriculture, Agricultural Research Service, Beltsville, MD. FADDL = U.S. Department of Agriculture, Foreign Animal Disease Diagnostic Laboratory, Plumb Island, NY.)

Disease agent	No. positive/ No. tested	Diagnostic laboratory
Brucella canis	0/120	OADDL
Brucella abortus	17/120	FSBL
Brucella abortus	6/17	FSBL
Brucella abortus	12/17	FSBL
Brucella abortus	5/17	FSBL
Brucella abortus	2/17	FSBL
Brucella abortus	5/17	FSBL
Brucella abortus	11/80	FADDL
Dirofilaria immitis	5/105	IDDEX
Canine distemper virus	0/80	FADDL
Canine distemper virus	0/166	OADDL
Phocine distemper virus	0/80	FADDL
Phocine distemper virus	0/166	OADDL
Porpoise morbillivirus	1/166*	OADDL
Dolphin morbillivirus	2/166*	OADDL
Phocine herpesvirus 1	0/166	OADDL
Marine herpesvirus 206	2/120	LCS
Human herpesvirus II	1/120	LCS
Leptospira pomona	0/120	LCS
Caliciviruses	0/120	LCS
CA sea lion rotavirus A111R	0/120	LCS
Walrus adenovirus W77R	4/120	LCS
Walrus enterovirus 7-19	0/120	LCS
Walrus retrovirus T2/19	1/120	LCS
Chlamydia psittaci	46/80	NVSL
Toxoplasma gondii	2/118	ARS
San Miguel sea lion virus (12)	0/80	FADDL
Vesicular Exanthema of Swine (12)	0/80	FADDL
Seal influenza virus	0/80	FADDL

*In early 1999, 47 additional Hawaiian monk seal serum samples were obtained (including retesting 2 of the 3 individuals shown here as seropositive to porpoise or dolphin morbillivirus). All sera were found negative for distemper and morbillivirus.

Plans for FY 2000 include a disease/health survey of the monk seal population at Midway Atoll (potential recipient population for translocated seals). This project will also focus on continued health and disease monitoring of the monk seal. Protocols for necropsy, specimen collection, serum banking, chemical restraint, and hematology have been developed and are being updated annually. A detailed reference collection is being compiled on health and disease of Hawaiian monk seals and other marine mammals. All previously collected biological specimens (i.e., serum, tissue samples from necropsies, etc.), and reports (i.e., examination forms, necropsy reports, etc.) are being catalogued and stored in a central location. Previously collected data on hematology, serum biochemistry, and other sample analyses are being incorporated into a comprehensive relational database. All of this effort is designed to improve our understanding of health and disease in wild monk seals, and thereby better enable us to enhance the species' recovery.

Captive Hawaiian Monk Seals

At FFS, the severe drop in juvenile survival represents a serious loss of the species' reproductive potential. That potential has been salvaged by rehabilitating undersized female pups and releasing them into the wild at Kure or Midway Atoll. In 1995, 12 pups were captured at FFS for rehabilitation on Oahu with the goal of returning them to the wild at Midway Atoll. After arriving on Oahu, 10 of the 12 seals developed an eye condition of unknown origin that resulted in their blindness, and 2 died later from bacterial infections unrelated to the eye problem. In June 1997, a panel of independent veterinary and wildlife experts deemed the seals unreleasable into the wild and recommended that they remain permanently captive. The annual cost of caring for these seals ranged from approximately $250,000 to $300, 000 and thus compromised the program's ability to finance other high-priority projects to enhance monk seal recovery. After an exhaustive national search for a facility that could provide proper care, husbandry, and access for continued research, Sea World of Texas was identified as the best possible site for relocating the seals (Fig. 6a). On April 11, 1999, the 10 captive monk seals were permanently relocated from the National Marine Fisheries, Kewalo Research Facility in Honolulu, Hawaii, to the Sea World of Texas in San Antonio, Texas (Fig. 6b).

Upon arrival, the seals were placed in a quarantine pool, began eating immediately, and showed no sign of stress from the transport. On April 20, 1999, the seals were moved into a permanent enclosure, where they continue to receive quality care and are reported to be in excellent condition.

Figure 6. a) Releasing a seal at Sea World of Texas, San Antonio. b) Four of the relocated seals in their new tank at Sea World.

PACIFIC SEA TURTLES

Background Information

Sea turtles are designated worldwide as threatened and endangered species. Population declines have been prominent in the Pacific Islands as the result of nesting habitat loss and excessive and widespread harvesting for commercial and subsistence purposes. The principal species of concern to Pacific islanders are the green turtle (*Chelonia mydas*) and the hawksbill (*Eretmochelys imbricata*). Both turtles are the focus of considerable conservation efforts by the Regional Marine Turtle Conservation Programme (RMTCP) of the South Pacific Regional Environment Programme (SPREP) based in Apia, Western Samoa. The SPREP is a non-governmental organization providing assistance to the environmental needs of 22 Pacific island nations. The SWFSC Honolulu Laboratory plays an important role in assisting SPREP in the conduction of the RMTCP. There is presently the strong desire by native inhabitants of many Pacific islands to reverse declining trends of sea turtles so as not to lose an acknowledged important part of their cultural and nutritional way of life. This task will not be easy due to inherent biological constraints of most sea turtles, which include extensive oceanic migrations for reproduction, vulnerability to predation, unknown pelagic life stages, and slow growth resulting in delayed sexual maturity of 25 or more years.

There are only two populations of loggerheads (*Caretta caretta*) in the Pacific, one originating in Australia where serious declines are occurring, and the other in southern Japan where numbers of nesting females appear to be stable. Leatherbacks (*Dermochelys coriacea*) inhabiting the Pacific mainly originate from nesting beaches in Mexico and Costa Rica where significant declines have been documented, in Indonesia where their status is uncertain but possibly stable, and Malaysia where the nesting colony is nearly extinct despite 30 years of conservation measures. Both leatherbacks and loggerheads are the species of principal concern with regard to incidental take in pelagic longline and other commercial fisheries of the Pacific conducted mainly by Japan, Taiwan, Korea and, to a lesser extent, the United States.

Green turtles in the Hawaiian Islands are genetically discrete and geographically isolated. Under the protection of the U.S. Endangered Species Act, this population has responded favorably to 21 years of recovery and research efforts by the SWFSC Honolulu Laboratory working in cooperation with the U.S. Fish and Wildlife Service, the State of Hawaii, and several private conservation organizations (Figure 1). The greater numbers of green turtles in waters around the main Hawaiian Islands have resulted in more opportunities for tourists and local people to view turtles in the water, in the same manner that humpback whales are an ecotourism

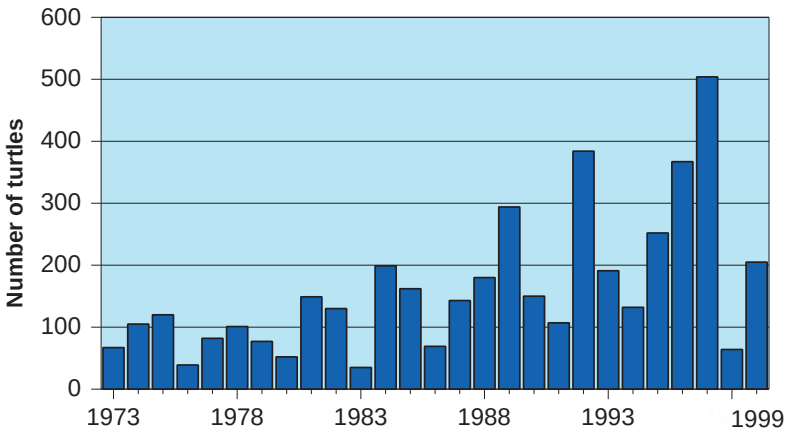


Figure 1. The number of green turtles nesting at the index study site of East Island has tripled since system monitoring started in 1973. 1997 was the highest year on record followed by a very low year in 1998. Interannual variations in green turtle nesting such as this are known to occur worldwide.

attraction. The successes thus far achieved in the biological recovery of the Hawaiian green turtle population constitute a model example in research and management for the rest of the Pacific islands. The olive ridley (*Lepidochelys olivacea*) nesting in the East Pacific has also shown a significant population increase in recent years under protective management and research by Mexican authorities.

Goal of The SWFSC Honolulu Laboratory Sea Turtle Program

The goal of the sea turtle program at the NMFS Honolulu Laboratory is to achieve the biological recovery and sound long term management of sea turtle populations in Hawaii and other U.S.-affiliated Islands in the Pacific Ocean and to assist Pacific Island and Pacific Rim Nations to recover sea turtle populations to the degree possible. To obtain the best scientific information possible to achieve this goal, research efforts at the Honolulu Laboratory emphasize the following:

- Investigations of the pathology, etiology, and epidemiology of fibropapilloma tumor disease to formulate strategies for containment, cure and prevention.
- Monitoring, assessment, and biological investigations at selected sea turtle breeding site where nesting takes place.
- Monitoring, assessment, and biological investigations at selected sea turtle foraging pasture aggregations in benthic habitats of coastal waters.
- Developing comprehensive computer simulation models and other quantitative tools to monitor population trends in order to better facilitate sea turtle recovery efforts and to assess impacts of fishery bycatch.
- Assessing post-hooking survival, movements and ecology in pelagic habitats and mitigation relating to bycatch of sea turtles in longline fishing.
- Conducting cooperative research, technical assistance and research training with Pacific Island and Rim Nations to promote the collection, analysis, and sharing of sea turtle data, including fishery bycatch data.

Major Research Activities

Investigation of Fibropapilloma Disease

Fibropapilloma (FP) is a tumor-forming, debilitating and often fatal disease of sea turtles that has

Figure 2. Heavily tumored turtle with fibropapilloma disease.

Figure 3. Massive internal lung tumor found in a necropsied green turtle

rapidly emerged in the past decade as a potentially serious threat to populations worldwide (Figure 2). This sickness has emerged as a significant issue regarding sea turtles and their habitats at certain sites worldwide including Hawaii, Florida, Barbados, Australia, and the Pacific (coasts of Mexico and Costa Rica). The disease is manifested by the formation of multiple fibrous masses of tissue 1 mm to 30 cm in diameter growing from the eyes, flippers, neck, tail, seams of scutes, and in the mouth.

The tumors also form in the internal organs (Figure 3). Although most FP tumors are histologically classified as benign (noncancerous), they can significantly disrupt and destroy the vital life functions of breathing, feeding, vision, and swimming. In advanced stages of the disease, turtles will often be lethargic, emaciated with soft and sunken plastrons, and prone to stranding ashore. Abnormal serum chemistry and hematology frequently are present. In addition, the pathology of FP is often associated with heavy burdens of internal parasites consisting of spirorchid cardiovascular flukes. FP has been shown to be transmissible in laboratory studies using injected cell-free tumor extracts.

Strandings of dead or even live turtles offer an array of special research opportunities that are impossible or difficult to pursue by other avenues. In the Hawaiian Islands, an integral component of this research includes a stranding and salvage research program started in 1982. This activity is carried out in partnership with the State of Hawaii's Department of Land and Natural Resources, the Southwest Region Pacific Islands Area Office, and the University of Hawaii-JIMAR and Marine Option Program. Reports of strandings from the public, as well as from county, state, and federal personnel on six major

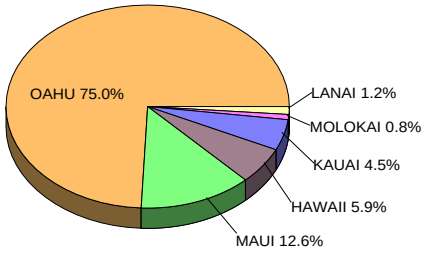


Figure 4. Green turtle strandings in the Hawaiian Islands by island, 1982-98 (N=2377).

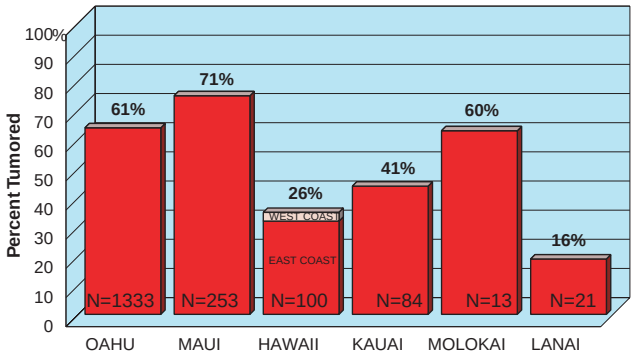


Figure 5. Data are based upon 1804 turtles examined for tumors over 17 years (1982-1998). Only two turtles with tumors have ever stranded along the West coast of the Island of Hawaii, one in 1986 and the other in 1992.

inhabited Hawaiian Islands, form the basis for initiating a response to collect data or acquire the turtle. The primary objective of the stranding research program in the Hawaiian Islands at present is to obtain information relevant to the epidemiology of FP. Strandings have increased annually over 17 years, from 10-20 cases in the early 1980s to 200-300 cases in the late 1990s. Most occur on Oahu (Figure 4). Strandings have decreased on Maui since a record high of 46 in 1996, but tumor prevalence here remains the highest of any island (Figure 5). Strandings occur evenly throughout all months of the year with no seasonal variation. No variation exists in the monthly percent occurrence of tumored turtles.

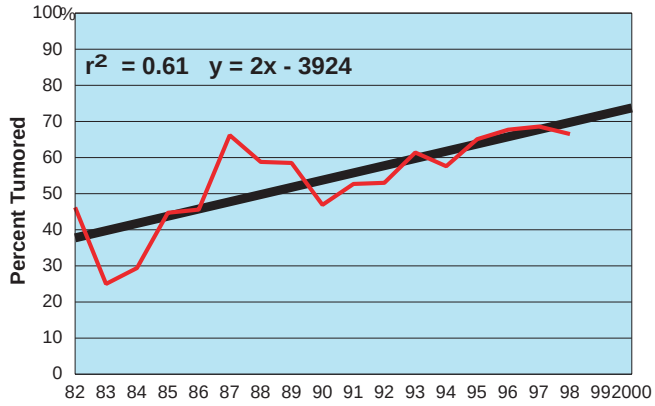


Figure 6. The percent tumored green turtles in strandings recorded throughout the Hawaiian Islands has fluctuated over the past 17 years, but remained high at 65-70% since 1995 (N=2377).

The prevalence of FP has remained high in stranded turtles (Figure 6) and at key long-term in-water study sites of Kaneohe Bay, Oahu and Palaau, Molokai where live turtles are sampled safely by net and hand capture (Figure 7). Prevalence of FP in strandings has ranged from 39%-69% over the past decade. The juvenile size-class accounts for the majority of strandings, and this group also has the highest frequency of tumors. In contrast, no cases of FP have as yet been encountered among the 600 turtles tagged and assessed along the 100-km western coastline of the island of Hawaii. The severity of cases of FP, based on a progressive tumor scoring system of 0-3, has declined in Kaneohe Bay from 1989 to 1997. The growth rates of turtles with severe FP in Kaneohe Bay are significantly slower than moderately or unafflicted turtles (1.0 vs. 2.2 cm/yr in carapace length). The manifestation of mouth tumors with significant glottal (air passage) invasion is a unique and especially damaging aspect of fibropapillomatosis in the Hawaiian Islands.

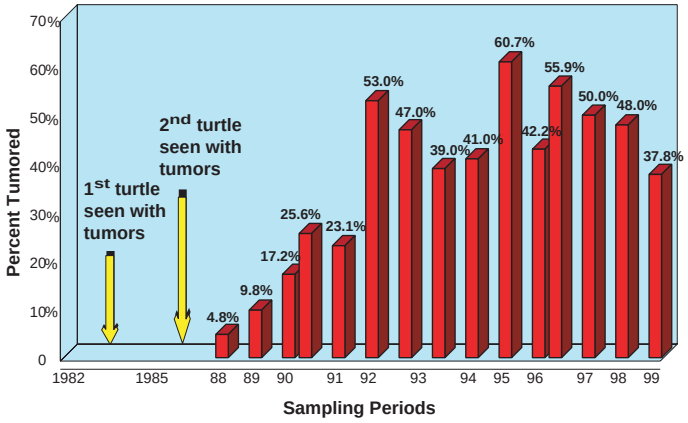


Figure 7. Prevalence of tumors at Palaau, Molokai (N=1312).

Mouth tumors and mouth and eye tumors in combination are highly prevalent in stranded turtles and their frequency has increased since 1990 (Figures 8 and 9). Oral tumors are present in 17% of FP cases. Internal tumors have increased in frequency since 1990. Up to 87% of FP turtles that are recaptured show an increase in severity, while very few (4%-8%) exhibit regression.

Figure 8. Oral tumors commonly found in green turtles stranded in the Hawaiian Islands.

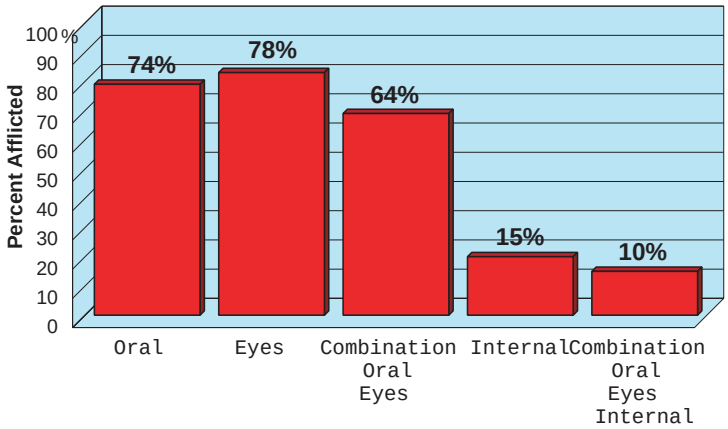


Figure 9. Anatomic location of tumor affliction for green turtles stranded and necropsied in the Hawaiian Islands.

Highly specialized Polymerase Chain Reaction Amplification and other techniques have identified an alphaherpesvirus, a retrovirus, and a papillomavirus in FP-afflicted tissues as the result of collaborative research with Cornell University, the University of Florida, JIMAR, and the University of Hawaii's Retrovirus Research Laboratory. Virus isolation efforts are in progress as a prerequisite for transmission studies to verify the disease-causing agent(s). Virus-free cell cultures using embryonic tissues of Hawaiian green turtles have been established for in vitro studies by the USGS National Wildlife

Health Center (NWHC). Representational Difference Analysis (RDA) screening for viruses is underway in collaboration with the Institute for Virology in Mainz, Germany. Laboratory techniques have been developed in collaboration with the Honolulu Field Station of NWHC to measure the humoral (antibody) and cellular (cell mediated) immune responses of clinically healthy green turtles held in captivity at the Kewalo Research Facility. Research has recently been completed to measure the immuno-competence of turtles in the wild at FP and non-FP habitat locations.

Benthic dinoflagellates, *Prorocentrum* spp., have been identified and quantified on algae and seagrass consumed by Hawaii's green turtles in a field study conducted in collaboration with the Florida Department of Environmental Protection. Nearshore coastal foraging habitats at high-risk for FP have a high prevalence and abundance of *Prorocentrum* spp. Non-FP foraging areas (the entire west coast of the Island of Hawaii) have very low *Prorocentrum* spp. These dinoflagellates are known to produce okadaic acid, a biotoxin shown to promote tumors in mice. Preliminary analysis of green turtle tissues has confirmed the presence of okadaic acid.

The University of Hawaii is analyzing remote videotape of the cleaning relationships between Hawaiian reef fishes and green turtles to provide baseline data on the potential role of carnivores transmitting FP between turtles. Turtles with FP may also be deterred from visiting cleaning sites due to painful bites to tumors by fishes. Tissues from cleaner fishes are being tested for oncongenic viruses.

Mexus Pacifico FP collaborative research of Eastern Tropical Pacific Mexican sea turtles has continued to be a highly successful cooperative study, involving information exchange and research training. This project is conducted with Dr. Javier Vasconcelos (Director) and his staff of the Centro Mexicano de la Tortuga INP sea turtle research station in Oaxaca, Mexico. A 14-day collaborative investigation was recently accomplished to assess histopathological characteristics and viral presence in tumors occurring on nesting olive ridleys. This specialized disease work is being conducted in part under contract by the Honolulu Laboratory to Drs. Alonso Aguirre and Terry Spraker, with veterinary technical assistance by Ms. Beth Zimmerman and others. There is an exceedingly high level of cooperation and mutual professional respect among all parties involved in the international effort to resolve a disease problem shared by Hawaii and the Pacific coast of Mexico.

The FP research currently in progress as noted in the above sections will be continued in FY 2000. In addition, as certain studies come to their appropriate conclusion, research will be expanded, fine-tuned, and enhanced in the areas of the Mexus Pacifico FP collaboration and the identification of the role of coastal ecosystem stresses and biotoxin-producing dinoflagellates in promoting FP.

Population Monitoring

The number of green turtles nesting in Hawaii each year has substantially increased at the index nesting site of East (Hikina) Island, French Frigate Shoals (FFS) in the Northwestern Hawaiian Islands (NWHI), from less than 100 in the early 1970s, to 200-500 in the 1990s (Figure 1). However, the total number of nesting females in the population is still well below historical levels and the fibropapilloma tumor disease continues to be a threat. The number of green turtles observed in waters around the main Hawaiian Islands has also increased significantly. Turtles in these foraging pastures are mostly immature turtles resulting from the increased nesting success. The successes thus far achieved in the biological recovery of the Hawaiian green turtle population constitute a model example in research and management for the rest of the Pacific islands. Continued annual systematic monitoring and tagging to determine number of nesters and their health status at FFS.

Modeling Turtle Population Dynamics and Assessing Human Impacts

Research to develop an understanding of sea turtle population dynamics is fundamental to management of human impacts and population recovery. The Honolulu Laboratory has continued research on a comprehensive population model for Hawaii green turtles and the populations of other species, particularly loggerheads and leatherbacks, that are caught and killed incidentally in the Hawaii-based longline fishery.

One of the critical determinants of population recovery of green turtles is the growth rate. Currently, Honolulu Laboratory scientists are collaborating with an expert in sea turtle skelechronology at the National Museum of Natural History to develop a model of Hawaii green turtle growth. In this research, the ages of specimens found stranded on Hawaii shores are estimated from the pattern of growth increments on their humeri (flipper bones). Preliminary results indicate a close correspondence between growth rates estimated from the humerus analysis and those measured directly from tagged and recaptured turtles. The growth analysis is a critical step in building a simulation model of Hawaii green turtle population dynamics that integrate information about the various life stages and processes.

The green turtle simulation model is just one of the models being developed using the computer simulation program TURTSIM. Other TURTSIM models are under development for Pacific populations of leatherbacks and Japanese loggerheads. Preliminary versions of the latter models have provided useful guidance in assessing the relative impacts of the Hawaii longline fishery, and other sources of human-caused mortality, on sea turtle populations.

Because most sea turtle populations inhabit the territorial waters of several countries, as well as the high seas during their life cycle, international cooperation is essential to the success of turtle research and recovery efforts. Accordingly, Honolulu Laboratory scientists are collaborating with sea turtle biologists in Mexico to develop a simulation model of the Mexican leatherback population that will take into account information about various human activities that have caused that population to decline.

Biology, Ecology, and Life History

Important progress is being made in understanding the biology, ecology, and life history of green turtles through long-term in-water monitoring at study sites throughout the Hawaiian Islands. This involves the systematic capture, health-screening, recording of morphometrics, and double tagging with internal PIT tags to permanently identify individuals and to quantify turtle aggregations at designated long-term coastal study sites. Growth rates of immature turtles, diets, habitat characteristics and use, daily foraging patterns, and trends in the number of turtles are being determined. For example, an analysis of data collected on 171 green turtles recaptured one or more times (of 1,458 tagged) at Palaau, Molokai yielded a mean growth rate of only 2.1 cm per year in carapace length. The use of high technology acoustic telemetry and dive recorders is revealing that green turtles undergo exceedingly limited daily movements between underwater resting areas and sites where feeding occurs on selected seaweeds.

Satellite Tracking to Estimate Post-Hooking Survival

This research was initiated in June 1997 by the Honolulu Laboratory working in partnership with the SWR Observer Management Program. To date, small satellite transmitters have been deployed from Hawaii-based commercial longliners on 31 hooked loggerheads, 6 olive ridleys, and 1 green turtle (e.g., Figure 10). Twenty-seven of the deployments resulted in pelagic trackings ranging from 0.2 to 8.2 months duration covering distances of 13-7,282 km (Figure 11). The remaining 11 deployments

produced no tracking data, and all of these involved turtles that were classified as “deeply hooked” (hook lodged in the esophagus and impossible to remove). Of the 27 tracked turtles, 14 were deeply hooked and 13 “lightly hooked” (the hook was in the mouth or elsewhere allowing easy removal). There were no significant differences between these two groups for the duration of transmissions in months (3.4 ± 2.1 deep versus 3.5 ± 2.7 light) or the distance the turtles traveled (2,354 ± 1,927 km deep versus 1,843 ± 1,385 km light). The full analyses of these data are in progress.

Figure 10. Incidentally captured pelagic loggerhead turtle fitted with a satellite transmitter to study longline fishery interactions.

The results of satellite tracking research relevant to loggerhead pelagic foraging habitat is presented in the Fisheries Oceanography section of this Program Review document.

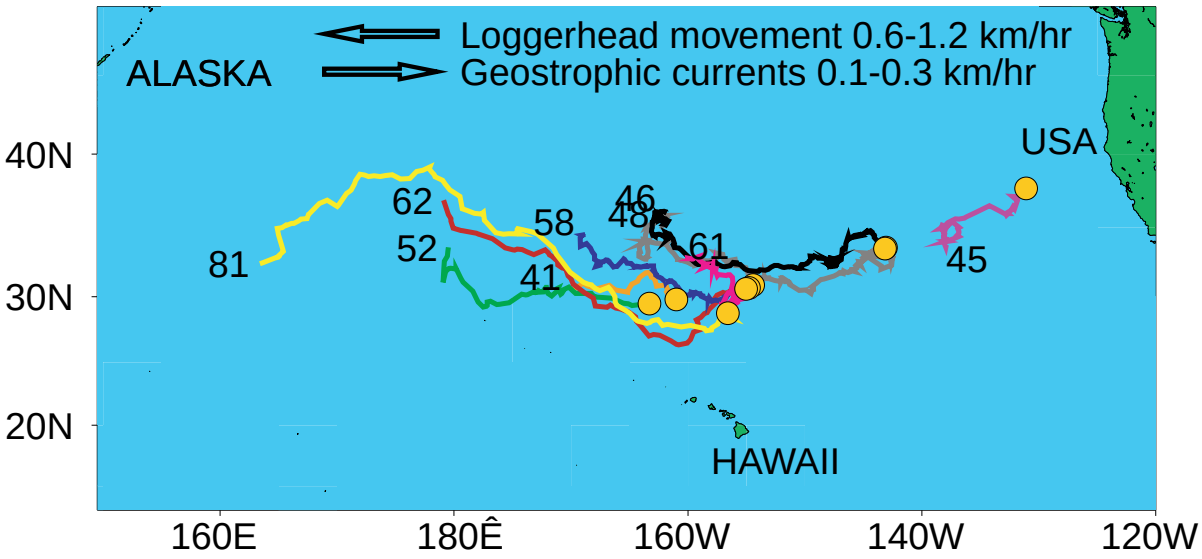


Figure 11. East-to-west movement of nine pelagic loggerhead turtles in the North Pacific Ocean as determined by satellite telemetry. The straight carapace lengths of the turtles are shown as the endpoint of each tracking line.

INTERACTIONS OF THE HAWAII LONGLINE FISHERY WITH SEA TURTLES AND SEABIRDS

Background Information

During fishing operations by Hawaii-based pelagic longline vessels, sea turtles, and seabirds occasionally become hooked or entangled in the fishing gear. Almost all of the seabirds are dead when the longline is retrieved. Most of the sea turtles are released alive but affected to an unknown degree by injury and trauma induced by their capture. Mortality resulting from the incidental capture in longline gear is a cause of concern because the affected populations are classified as endangered or threatened under the Endangered Species Act or protected by other statutes. Under a NMFS Biological Opinion concerning the longline fishery, NMFS is required to monitor the incidental takes and mortality of sea turtles and seek ways to reduce them. A similar requirement applies to incidental takes and mortality of seabirds. The data for monitoring take levels and understanding factors that affect takes are collected through a NMFS observer program operated by the Southwest Region and mandatory longline logbooks submitted to NMFS by longline vessel captains.

Goals and Objectives

- To estimate takes and mortalities of sea turtles and seabirds in the longline fishery.
- To identify factors that may be associated with high take rates of sea turtles and seabirds.
- To develop and apply sound statistical protocols to the estimation and analysis of incidental take levels and contributing factors.
- To assess the impacts of incidental takes on populations of sea turtles and seabirds.

Major Accomplishments and Research Activities

Interactions with Sea Turtles

The Honolulu Laboratory has continued to conduct analyses of the interactions of the Hawaii-based longline fishery with sea turtles. A primary objective is to estimate the numbers of turtles taken and killed annually in the fishery. Results are provided to the Southwest Region, which monitors the incidental take and mortality in relation to levels authorized for each species under the Biological Opinion for the fishery. The Region issues an annual report of take and mortality levels and other results of the observer program.

Annual turtle takes and kills for all turtle species were estimated using a combination of data collected from a small (~5%) sample of longline trips on which NMFS observers were deployed and the daily logbook records reported by longline vessel captains from all fishing trips. For loggerhead sea turtles, the species most frequently involved in interactions with longline gear, the estimates of take were computed in two steps. First, a regression tree technique was applied to the observer data to identify statistically significant predictors of loggerhead take from a multitude of factors describing longline

fishing practices and the ocean environment and produce a statistical model from which loggerhead takes during unobserved longline trips can be estimated from logbook data. The model was then applied to the logbook records and the total loggerhead take estimated (Table 1). The uncertainty in the estimates, expressed as 95% confidence bounds, was assessed with a bootstrap technique.

Table 1. Estimates of annual takes and kills of sea turtles in the Hawaii longline fishery and 95% confidence bounds. Annual takes recorded by NMFS observers on monitored fishing trips also given.

		Annual Observed Take	Total Annual Take Estimate [95% CB]	Total Annual Kill Estimate [95% CB]
Loggerhead	1994	11	427 [260 -- 610]	75 [41 -- 110]
	1995	19	334 [242 -- 518]	58 [41 -- 93]
	1996	27	390 [264 -- 537]	68 [45 -- 98]
	1997	22	338 [244 -- 475]	59 [39 -- 88]
	1998	48	363 [262 -- 515]	63 [43 -- 92]
Leatherback	1994	8	154 [102 -- 205]	10 [0 -- 20]
	1995	4	163 [107 -- 218]	10 [0 -- 21]
	1996	9	166 [111 -- 221]	11 [0 -- 22]
	1997	12	172 [114 -- 226]	11 [0 -- 23]
	1998	5	174 [114 -- 231]	11 [0 -- 23]
Olive Ridley	1994	3	100 [53 -- 148]	33 [13 -- 53]
	1995	4	110 [59 -- 161]	37 [15 -- 58]
	1996	9	114 [65 -- 167]	38 [16 -- 60]
	1997	3	110 [60 -- 163]	37 [15 -- 58]
	1998	5	118 [65 -- 173]	39 [15 -- 61]
Green	1994	2	30 [10 -- 51]	0.3 [0 -- 0.6]
	1995	0	31 [8.9 -- 53]	0.3 [0 -- 0.6]
	1996	3	34 [12 -- 56]	0.3 [0 -- 0.7]
	1997	0	31 [9 -- 53]	0.3 [0 -- 0.6]
	1998	2	35 [12 -- 58]	0.3 [0 -- 0.7]

This year, beside using more information (observer data from 1994-1998), the regression tree analysis of loggerhead takes tested the predictive ability of additional factors, including the distances of the fishing location north or south of a series of sea surface isotherms and a series of wind curl factors that could indicate aggregation or dispersal of the surface flotsam that turtles eat. The final, pruned regression tree for loggerhead turtles indicates that the most significant predictor of loggerhead takes was the position of the longline set relative to the 14°C isotherm (Fig. 1). Thus the statistical model tracks to some degree the seasonal and interannual shifts in the oceanographic regime.

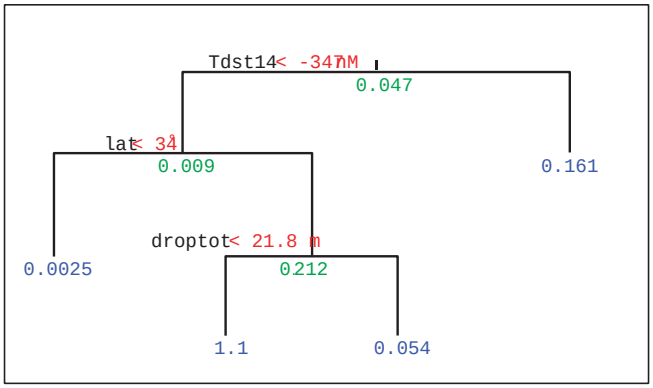


Figure 1. Loggerhead regression tree. Statistically significant variables in order of importance are: "Tdst14" - the closest distance north (positive) or south (negative) to the 14 degree C isotherm; "lat" - the latitude; and "droptot" - the sum of the floatline length and the dropper length. Labels at nodes and end points give expected takes per longline set.

Although the regression tree method was applied to all turtle species encountered in the Hawaii longline fishery, no significant predictors were found for leatherback, olive ridley, or green turtles. This is not surprising because the paucity of observed takes of those species (Table 1) means that a factor has to have a very strong effect to be a statistically significant predictor. For these three species, take estimates were computed by simply expanding the takes per set in the observer data by the total number of sets reported in logbook records.

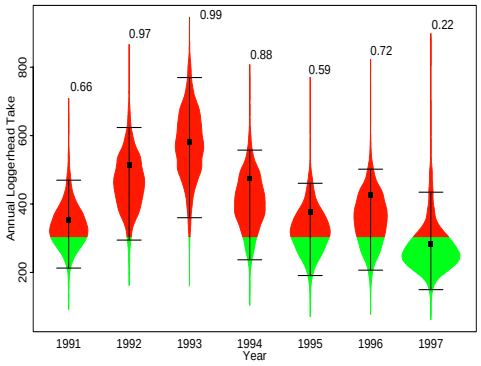


Figure 2a. Take estimates for loggerhead turtles. Point estimates with 95% confidence bounds superimposed on distributions of bootstrap estimates. The number above each distribution plot is the proportion of the distribution above the authorized level for loggerhead takes - the red portion of the distribution.

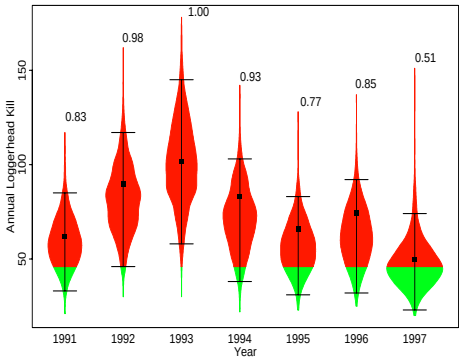


Figure 2b. Kill estimates for loggerhead turtles. Point estimates with 95% confidence bounds superimposed on distributions of bootstrap estimates. The number above each distribution plot is the proportion of the distribution above the authorized level for loggerhead kills - the red portion of the distribution.

Estimates of the number of turtles taken and killed in the fishery are computed (Table 1 and Fig. 2) by combining the take estimates with observer data on the condition of turtles taken in the Hawaii longline fishery and meager published information on kill per take in other longline fisheries. Estimates of post-release survival are expected to be improved as results emerge from the NMFS program to monitor the movements and behavior of turtles hooked and released using sophisticated satellite transmitters.

In addition to estimating turtle takes and mortalities, the Honolulu Laboratory is examining observer and any other relevant data to search for factors that may influence turtle takes and that may therefore suggest possible take mitigation measures. The significance of factors affecting turtle takes is determined as a spin-off of the statistical modeling to estimate annual takes. Three factors have been found to be statistically significant for loggerhead takes (Fig. 1). In order of effect, these are the location of the fishing operation in relation to the 14°C surface isotherm, the latitude of fishing, and the sum of floatline length and dropper length. No significant factors have yet been found for other species. This may simply reflect the difficulty of detecting effects in the presence of a high degree of variability and other statistical problems rather than a lack influence by these factors. Indeed, there has been an expectation that light sticks might attract sea turtles to longline hooks and thereby increase the likelihood of a take. In the regression tree models, derived from data aggregated over each set, light sticks were not found to be a significant predictor of take. A further analysis was done using more detailed data collected by observers on the proximity of hooked turtles to the nearest light stick. This study compared the distributions of these distances to the distributions expected if the turtles were hooked at random with respect

to light sticks. The results showed no effect of light sticks for loggerheads or leatherbacks. However, the statistical power to determine such effects is severely limited by the paucity of observed takes and high variability.

The statistical power to detect the effects of factors on turtle take from the available observer data is also reduced by the high degree of confounding of these effects in commercial fishing operations; commercial longline sets are made with very similar combinations of fishing gear variables chosen to maximize the catch of the target fish species. Much greater contrast between these operational factors could be achieved in a controlled longline experiment, using either a research vessel or chartered commercial longliner. This year a study was conducted to determine the statistical requirements of such experiments. The results suggest that because of the overall rarity of turtle takes and high set-to-set variability of take rate in the Hawaii fishery, controlled longline experiments sufficient to detect even threefold differences in mean take rates between factors may be prohibitively expensive.

Interactions with Albatrosses

With the increasing concern about the capture of seabirds in longline fisheries worldwide, the Honolulu Laboratory has been investigating albatross catches in the Hawaii longline fishery. As with sea turtles, annual takes of black-footed and Laysan albatrosses in the longline fishery were estimated with regression tree models. In addition to the multiplicity of factors tested for sea turtles, the albatross analysis included additional predictors, including composite measures of the proximity of longline sets to albatross nesting colonies in the Hawaiian Islands National Wildlife Refuge. These variables took into account differences in colony size and assumed a diminution of effect with distance from a colony. For both albatross species, the estimated regression tree showed the most important predictor of take to be a nest proximity variable (Figs. 3 and 4). In a manner similar to the turtle analysis, annual albatross catch estimates were computed along with bootstrap confidence bounds (Table 2).

Table 2. Estimates of annual incidental takes of albatrosses in the Hawaii longline fishery and 95% confidence bounds. Annual takes recorded by NMFS observers on monitored fishing trips also given.

	Blackfooted Albatross		Laysan Albatross	
	Observed Take	Total Take Estimate [95% CB]	Observed Take	Total Take Estimate [95% CB]
1994	126	1994 [1508 -- 2578]	73	1828 [933 -- 2984
1995	105	1979 [1439 -- 2497]	107	1457 [767 -- 2308
1996	59	1568 [1158 -- 1976]	31	1047 [569 -- 1610
1997	107	1653 [1243 -- 2102]	66	1150 [599 -- 1875
1998	46	1963 [1479 -- 2470]	56	1479 [822 -- 2336

In addition to providing albatross incidental take estimates, the Honolulu Laboratory assisted the Council by estimating the proportion of the total albatross takes that occurs within various oceanic areas in the neighborhood of the albatross nesting colonies. The Council staff used this information as part of a study of possible time-area regulations to mitigate albatross mortality. The regression trees for both albatross species (Figs. 3 and 4) showed that the proximity of fishing location to the nesting colonies is a key predictor of the likelihood of catching albatrosses. Other factors (longitude for black-footed albatross and year for Laysan albatross) are much less important. Operational factors, such as dyeing

the bait blue, placing weights on the droplines, and deploying tori lines, have been shown to be significantly reduce albatross interactions (see below), but these factors were not amenable to testing with observer program data.

Honolulu Laboratory staff also provided other scientific support to the Council regarding the longline-albatross interaction issue. Several Laboratory staff participated in the Council's Black-footed Albatross Population Biology Workshop in October 1998 and made substantial contributions to the workshop proceedings and report. This included a comprehensive review of information on black-footed albatross takes in North Pacific gillnet and longline fisheries, including the Hawaii longline fishery. Laboratory scientists also provided information to assist Council staff and a University of Hawaii professor in a study of time-area closure options to reduce the level of longline interactions with albatross species.

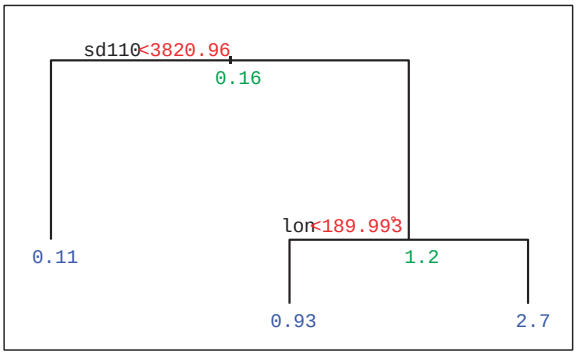


Figure 3. Blackfooted albatross regression tree. Statistically significant variables in order of importance are: "sd110" - a composite next proximity variable with a scale parameter of 100 nM (see text); and "lon" - the longitude. Labels at nodes and end points give expected takes per longline set.

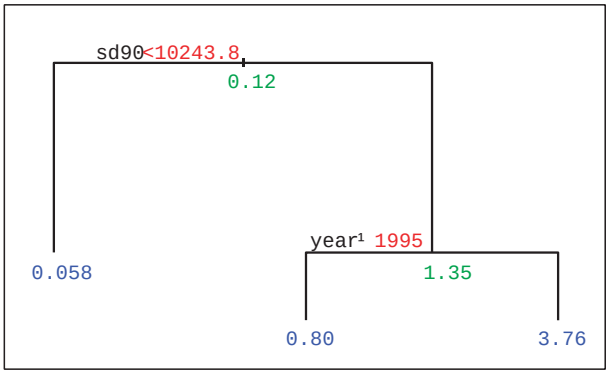


Figure 4. Laysan albatross regression tree. Statistically significant variables in order of importance are: "sd90" - a composite nest proximity variable with a scale parameter of 90 nM (see text); and "year". Labels at nodes and end points give expected takes per longline set.

Seabird Deterrent Research

In February the Honolulu Laboratory completed a very successful month-long research cruise on *Townsend Cromwell* that tested various methods of keeping seabirds from being hooked in longline fishing operations. The cruise tested the tori line (a kind of "scarecrow") as well as weighted bait, and blue-dyed bait (Fig. 5), for their efficacy in deterring birds from being caught in the Hawaii-based longline fishery. Hooking of seabirds by the Hawaii fishery occurs mostly in the swordfish fishery north of the archipelago where albatross and swordfish are most abundant. In the swordfish fishery, the common practice of deploying longline gear after dark greatly reduces seabird contacts with baited hooks, but occasional daytime deployments can cause deaths of seabirds, especially black-footed albatross and Laysan albatross. Albatross contact with longline may also occur as the gear is hauled, which commonly takes place in daylight. Results of the study showed that all three deterrents greatly reduced the number of times albatross came in contact with longline baits. The advantage of using *Townsend Cromwell* for this research was that fishing operations could be controlled to improve the opportunities for observation,

Figure 5. Dyeing the squid bait dark blue, using food coloring, makes the bait much harder for the albatross to get.

comparison, and statistical analysis. For example, by setting gear in daylight the scientists greatly increased the number of bird interactions with the gear in the presence and absence of each deterrent method.

A typical swordfish longline is left in the water most of the night, and then the fishing vessel drives down the line, hauling it back onto a reel and removing the catch. During a set, birds attack the baited branch lines as they are tossed out behind the vessel until they sink beyond reach. Albatross cannot dive or swim very deep, so once the baits have sunk some distance underwater they stop catching birds and start catching fish. In the Hawaii-based swordfish fishery the branch lines are already weighted, but adding more weight to the bait to speed the sinking has been recommended as a bird deterrent. Fishermen around the world have problems losing bait to albatross, and they have developed several methods to keep birds away. "Tori" means bird in the language of the Japanese fishermen who developed the tori line, which is a rope with fluttering streamers towed from a high point or pole mounted over the stern of a fishing vessel (Fig. 6). The streamers dangle in the air and water over the baits, repelling the birds until the baits sink beyond reach. Tori lines and dyed bait are not yet widely used in the Hawaii-based fishery, partly because fishermen usually find other ways to avoid birds, such as setting at night. Hawaii fishermen have tried dyeing their bait a deep blue with food coloring so that it becomes hard for the birds to see.

Figure 6. A tori line is like a scarecrow. It is dangled from a pole to stream over the baits behind the vessel.

On the research cruise albatross attempt to take longline baits were observed in 24 consecutive longline sets which repeatedly tested the three deterrents (tori line, blue bait, and weighted bait) in a random order. About 280 hooks were deployed on each set, and about 70 hooks on each set were deployed without any deterrent (as a control). No birds were hooked during the NMFS research cruise, even during control portions because large safety pins (net pins) were used instead of hooks (Fig. 7). When birds swallowed these "safety hooks" they easily regurgitated them. Albatross routinely regurgitate food to feed their young and to rid themselves of indigestible material such as squid beaks. Observers watched all setting and hauling operations, calling out to recorders the number of each species seen attempting to reach baited lines (chasing, landing, or diving) and the number contacting the baits. Other observers with binoculars watched for incidences in which birds actually swallowed the baits.

Figure 7. Easily regurgitated net pins were substituted for hooks in the research to reduce injury to the albatross.

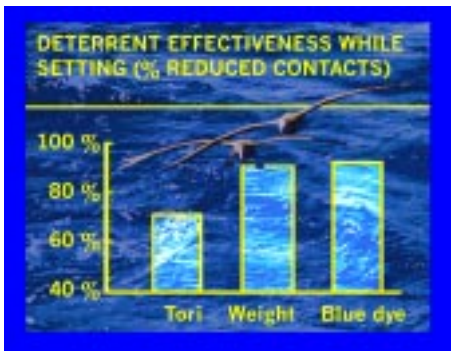


Figure 8. Reduction rate (%) in albatross contacts with bait in comparison to control treatments.

Cruise results indicated that all of the deterrents substantially reduced bird contacts with baits (Fig 8). Blue-dyed bait and weighted bait each reduced the number of times birds contacted baits by about 90% during setting. The tori line reduced bird contact with baits by about 70% during setting. Albatross are

most often killed by longlines during setting because if they are hooked or entangled they sink with the gear and are drowned, whereas if they are hooked during the haulback they can be released. The deterrents did not seem as effective during haulback, and these results will require further analysis. Results of the research have been submitted for publication.

No short-tailed albatross were seen during the hundreds of hours spent observing thousands of birds. Short-tailed albatross have the smallest population of any albatrosses in the North Pacific, and they are very rare in Hawaiian waters. Boobies, shearwaters, frigate birds, terns, and petrels were identified in addition to albatrosses but not one of these other birds ever contacted the baited lines. Black-footed albatross plumage changes with age. Less than one-year-old birds have uniformly dark-brown plumage. After their first year they acquire white-tipped tail coverts (Fig. 9). Old birds may reach 40 years in age. During haulback, when birds approached the vessel closely, NMFS scientists recorded that more than half of the black-footed albatross had juvenile plumage, and that about 80% of the black-footed albatross that took baits off the lines were these young birds (Fig. 10). This result supports the idea that fishery-related mortality represents mostly young, inexperienced birds.

Figure 9. When less than 1 year old, black-footed albatross do not have white feathers near the tail as seen in this older bird.

Figure 10. The proportion of trailed baits taken by young albatross is much higher than the proportion of young birds following the ship.

FISHERIES OCEANOGRAPHY APPLIED TO MARINE ECOSYSTEMS

Background Information

Interannual and decadal variation in stocks of marine fishes and populations of protected species results from natural fluctuations in the ocean environment and human-induced impacts including harvesting, habitat loss, pollution, etc. An understanding of the variation in the ocean environment which may cause changes in the ecosystem is necessary before it can be known whether observed ecosystem variation is due to environmental changes or human impacts. Recent advances in satellite remote sensing and ocean circulation models have greatly increased our knowledge of ocean dynamics. The challenge is to understand the link between the ocean and ecosystem dynamics.

Goals and Objectives

The goal of the Honolulu Laboratory fisheries oceanography research is to advance our knowledge of ocean and ecosystem dynamics with particular focus on the Northwestern Hawaiian Islands and the central Pacific pelagic ecosystem.

Major Research Activities

Investigation of Loggerhead Turtle Forage Habitat.

There is concern about incidental catches of loggerhead turtles in the Hawaii-based longline fishery for swordfish. To learn more about the turtle forage habitat in the region of the swordfish fishery collaborative work was undertaken between staff in the Ecosystem and Environment Investigation and the Marine Turtle Research Program. Satellite remote sensing data of sea surface temperature (SST), chlorophyll, and geostrophic currents were used to describe the environment at and around the daily positions of nine loggerhead turtles tracked by satellite telemetry during 1997 and 1998. The results showed that all nine loggerheads traveled westward along two convergent oceanic fronts, against prevailing currents (Fig. 1). These fronts are characterized by gradients in sea surface height, producing

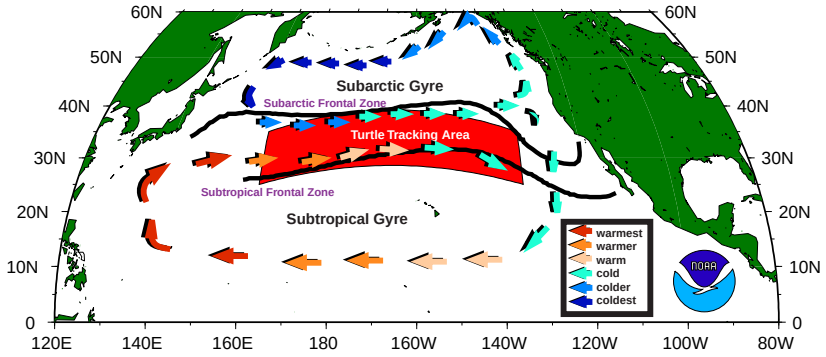


Figure 1. Schematic of the winter central North Pacific oceanography indicating the subarctic and Subtropical Gyres and Frontal Zones, arrows show gyre rotation and a rough gage of surface ocean temperature, and red box indicates the general region of the loggerhead turtle tracks in this study.

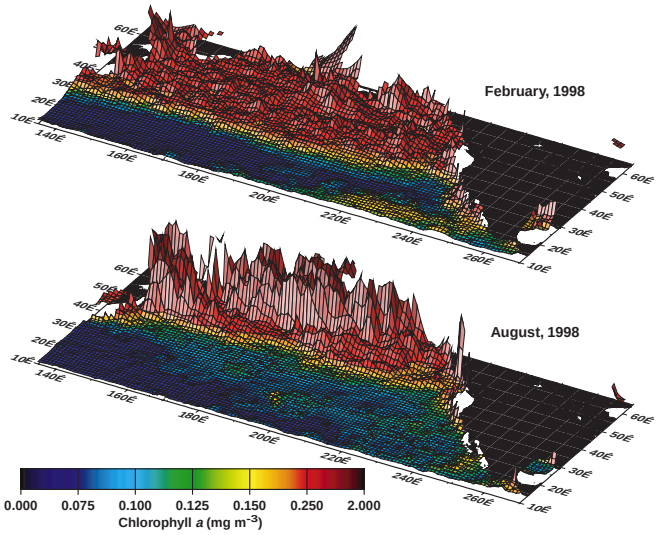


Figure 2. North Pacific surface chlorophyll from the SeaWiFS satellite sensor for February and August 1998. A dominate feature of these images is the Subtropical Chlorophyll Front, shown in yellow, as the boundary between the low surface chlorophyll water of the subtropical gyre and the high surface chlorophyll water to the north. This front is a migratory and forage habitat used by loggerhead turtles.

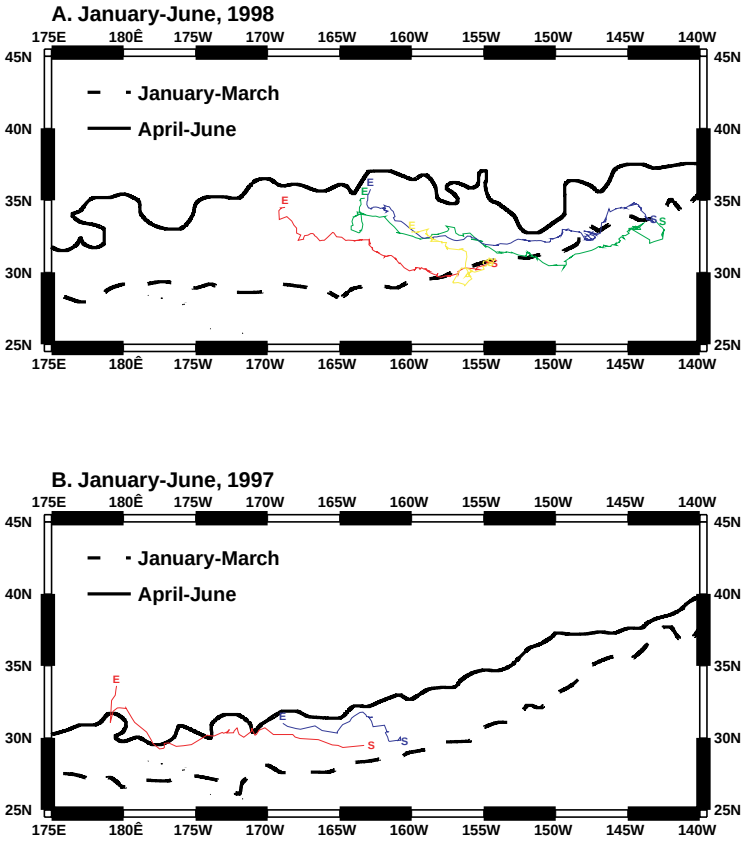


Figure 3. Quarterly position of the Subtropical Chlorophyll Front and tracks of six turtles for first and second quarters, 1997 and 1998. “S” and “E” denote starting and ending positions of each turtle track.

an eastward geostrophic current, gradients in surface chlorophyll, and SST. Six of the turtles associated with a front characterized by 17°C SST, surface chlorophyll of about 0.2 mg/m^3, and eastward geostrophic current of about 4 cm/s. This front is easily seen from satellite remote sensing of ocean color (Fig. 2). Interannual variation in the movement of this front appears to alter turtle migration (Fig. 3). The other three turtles associated with a front with 20°C SST, surface chlorophyll of about 0.1 mg/m^3, and eastward geostrophic of about 7 cm/s. These results explain why incidental catch rates of loggerheads in the Hawaii longline fishery are highest when gear is set at 17°C and 20°C SST. Further, from the seasonal distribution of longline effort relative to these fronts, it appears that the surface longline fishing ground lies largely between these two fronts during the first quarter and well to the south of the 17°C front but including the 20°C front in the second quarter. The turtle catch rates in the longline fishery are highest at the 17°C front, so an area or seasonal closure which separates the longline fishery from this front might effectively reduce interactions with turtles. A manuscript resulting from this work is in press at *Fisheries Oceanography*.

Physical and Biological Impacts of El Niño and La Niña

Analyses of long time series of sea surface temperature (SST) over the North Pacific show that during El Niño, SST in the central North Pacific is cooler than average while SST in the eastern equatorial Pacific is warmer than average. During the La Niña, SST in the central North Pacific is warmer than average while the eastern equatorial Pacific is cooler than average. Thus relative to SST, the central Pacific and eastern North Pacific appear to respond in the opposite direction. To further investigate impacts of El Niño and La Niña to the northern portion of the Hawaiian Archipelago, satellite remote sensed chlorophyll from SeaWiFs and sea surface height from the altimeter aboard TOPEX/Poseidon were used to describe the changes during the winter and spring of 1998 (El Niño) and 1999 (La Niña). During the 1998 El Niño, the winter monthly chlorophyll levels in the northern portion of the Hawaiian Archipelago were 50-100% higher than during the 1999 La Niña winter values. Sea surface height was 8-10 cm lower in the winter of 1998 than in the winter of 1999 (Fig. 4). The SST, chlorophyll, and sea surface height data all indicate that both the physical and biological response to El Niño/La Niña in the northern portion of the Hawaiian Archipelago is opposite from the classical pattern observed in the eastern tropical Pacific. In the northern portion of the Hawaiian Archipelago, during El Niño, there is a shoaling of the thermocline and subsurface chlorophyll maxima which lowers SST, sea surface height, and increases surface chlorophyll. During La Niña, the depth of the thermocline and chlorophyll maxima increases, the mixed layer becomes more stratified with SST and sea surface height increasing and surface chlorophyll decreasing. Subsurface data from research cruises in 1998 and 1999 confirm these changes in vertical structure.

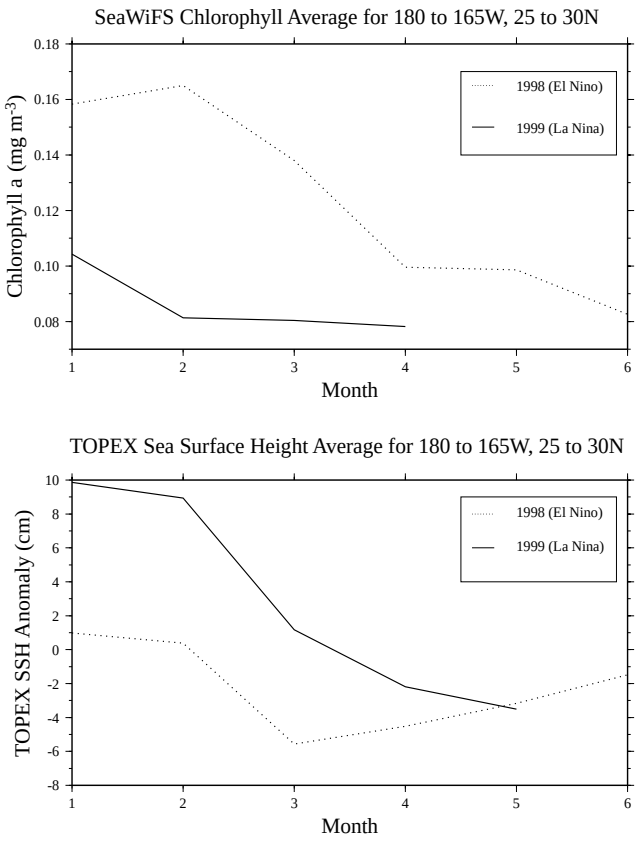


Figure 4. Mean monthly chlorophyll and sea surface height covering the northern portion of the Hawaiian archipelago, 180-165°W longitude, 25°-30°N latitude during January-June 1998, an El Niño period, and January-June 1999, a La Niña period.

While the El Niño/La Niña impacts in the northern portion of the Hawaiian Archipelago are not as extreme as found in the eastern tropical Pacific, they may still have ecosystem impacts. In a collaborative project with the Protected Species Investigations, we have documented an increase in monk seal pup girth for pups born during the last three El Niños (Fig. 5). We hypothesize that El Niños increase prey availability to pregnant seals, ultimately resulting in better pup condition at weaning, while La Niñas, with more vertically stratified conditions, decrease prey availabilty resulting in poorer pup conditions. This hypothesis will be tested after the 1999 La Niña, which we predict will lead to a decline in pup girth. A presentation on this work will be made at the Marine Mammal Conference in December 1999.

Monk Seal Axillary Girth at French Frigate Shoals and Laysan Island

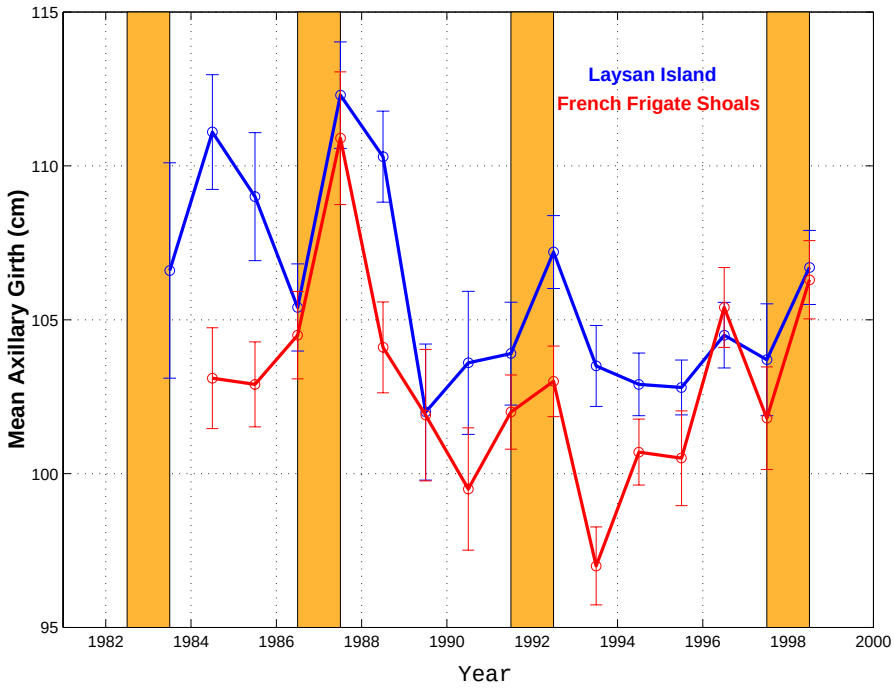


Figure 5. Time series of mean annual monk seal pup girth at French Frigate Shoals and Laysan Island with shading bars marking El Niño events.

Hawaiian Ocean Mixing Experiment

Honolulu Laboratory oceanographers are participating with investigators from five academic institutions on the Hawaiian Ocean Mixing Experiment (HOME), an integrated program funded by the National Science Foundation to study the role of tidally induced topographic mixing in maintaining the large scale thermohaline circulation of the world's oceans. Observed mixing rates in the pelagic ocean are an order of magnitude less than that required to maintain the large scale circulation. Recent observations suggest instead that most of the oceanic mixing occurs near significant topographic features, such as the Hawaiian Ridge. The challenge is to identify the mechanisms which are active over a sufficient space-time domain as to have a global impact.

Through this collaboration with HOME, Honolulu Laboratory oceanographers will have access to unique, high quality data sets and state-of-the-art instrumentation to examine the spatial and temporal variability of oceanographic conditions along the Hawaiian Ridge. These data sets will be utilized to examine the complex physical and biological interactions associated with the topography of the ridge.

This will provide an improved understanding of these dynamic ecosystems and an improved ability to manage the fishery resources and protected species of the Hawaiian Archipelago.

The goals of HOME are to quantify the rate of tidal energy loss to mixing at the Hawaiian Ridge and to identify the mechanisms by which energy is lost and mixing generated. HOME is challenged to develop a sufficiently comprehensive picture whose results can be generalized from the Hawaiian Ridge to the global ocean. The well-defined frequency of tidal forcing and the unique geometry of tidal scattering serve to focus the experimental design. Strong interaction between the barotropic tide and the Hawaiian Ridge is known to take place.

These goals will be achieved through a program of historical data analysis, modeling, a field survey, a near-field experiment, and a far-field experiment. Honolulu Laboratory oceanographers will assist the Historical Data Analysis component of HOME by processing and analyzing a 12- year time series of acoustic Doppler current profiler (ADCP) data and CTD/XBT data from NOAA ship *Townsend Cromwell* along the Hawaiian Ridge. The analysis and modeling efforts will support the design of the survey and field experiments. As the program progresses, a global model of the barotropic (depth-independent) tide and two models of the baroclinic (depth-varying) tide, all validated with near-Ridge data, will be applied to reveal the mechanisms of tidal energy conversion along the Ridge and to allow spatial and temporal integration of the rate of conversion.

If successful, HOME will yield an understanding of the dominant topographic mixing processes applicable throughout the global ocean. It will advance understanding of two central problems in ocean science--the maintenance of the abyssal stratification and the dissipation of the tides. The data will be used to improve the parameterization of mixing in models that presently assimilate TOPEX-POSEIDON observations. The improved understanding of the dynamics and spatial distribution of mixing processes will benefit long-term climate and fisheries research activities.

ORACLE DATABASE DEVELOPMENT

Background Information

Much of the Oracle database development work done this year at the Honolulu Laboratory was to make our data, descriptions of the data, and reports available electronically via the World Wide Web; adopt the NMFS guidelines for database management systems; and reduce our dependence upon database software not Y2K compliant. This work supports various regulations and issues identified in the NOAA Fisheries Information Technology (FIT) Principles approved by the National Information Management Board in 1997. These require that data be viewed as an agency asset, that it be directly available to appropriate users, and that the data be disseminated and protected in accordance with Agency guidelines. NOAA encourages the use of electronic workflow technologies to collect data and ensure timely delivery of information services. These activities were in support of the Paperwork Reduction Act 44 U.S.C. 3501-3520, the Freedom of Information Act 5 U.S.C. 552, while still requiring the protection of confidential data submitted to and collected by NOAA Fisheries pursuant to NOAA Administrative Order 216-100: Protection of Confidential Fisheries Statistics. Development of metadata, documentation for users of our data holdings, is also required in accordance with Executive Order 12906, 13 April 1994. Additionally, much work was accomplished developing an electronic map library of shorelines, bathymetry, substrate, and exclusive economic zone (EEZ) and providing reports employing fisheries data, maps, and satellite imagery.

Goals and Objectives

The management goals for Oracle database development are:

- An Oracle-based Honolulu Laboratory enterprise database holding and providing access to all data collected and maintained including monk seal, pelagic fisheries, sea turtle, environmental, other fishery/resource, and administrative data sets.

- Development of databases that are designed to support a wide range of Geographical Information Systems (GIS).

- Establishment of an infrastructure to facilitate the infusion of GIS technology into the workforce.

- Timely dissemination of data via the World Wide Web to Laboratory scientists, the WPRFMC, and in accordance with the Freedom of Information Act to all other users.

- The following objectives support accomplishing these goals:

- Conversion of all fisheries and related data collected by the Honolulu Laboratory into an Oracle database.

- Development and recording of metadata in accordance with Executive Order 12906, April 13, 1994 requirement to document and provide to users of our data stores.

- Development of automated map library and routines to provide displays of data.

- Development of security to prevent unauthorized accessing of data.

- Providing user access to fixed and customizable reports, data browsers, and to detailed data and documentation as appropriate via the World Wide Web.

Major Activities

- Emphasis this year was on loading as many data sets into Oracle as possible and developing timely access to these data via the World Wide Web. Approximately 50 additional data sets and their metadata have now been loaded into Oracle as flat files in an attempt to provide immediate availability of data for authorized members of the Laboratory Data management routines were provided to assist in loading both data and metadata that provide up-to-date documentation on the quality of the data and prevent the misuse and misrepresentation of information by constituents.

- Additional training has facilitated the ongoing development of user interfaces that provide access to the data with browsing, querying, and downloading functions. Some existing reports have been converted to Oracle, and several GIS applications have been developed with products available via the WWW. Geographic representations of lobster, pelagic, and bottomfish data have been developed, with a current emphasis on development of a database of maps for coral reefs as well as for both nearshore and pelagic ecosystems.

- The SWR PIAO Confidential Permit database system written in Rbase was analyzed and redesigned due to Y2K noncompliance by both the database software and data design problems. This redesign was coordinated with Doug Howard of NMFS HQ and Al Katekaru of the SWR PIAO office. Confidentiality requirements produced a restrictive view of only 8 of the 40 available fields for NMFS HQ and general users. These data are routinely accessed by NMFS HQ staff.

- Data Management routines were developed and successfully tested that provide scripts to automatically load metadata available from existing data previously loaded into Oracle in both flat file and model tables. This significantly reduced the time required to manually update metadata. Oracle forms were created to provide the ability to search existing metadata by types of data and display current status of the associated data sets. These Oracle forms were turned over to FDMP to permit entry of metadata, maintenance of data, and loading of reference tables in Oracle.

- Lobster Observer software was corrected and modified to reflect data requirement changes to the previous year's data. User documentation for Observers entering Oracle Lobster data was prepared. An Oracle form to query the data and permit downloading of data in standard ASCII format on Onaga or via the WWW was built. Documentation of the data entry scripts for this system was provided and responsibility turned over to the data managers in FMPI for upkeep of the software for this year's lobster data entry modifications.

- Further development of the existing enterprise model was closed out. Problems with the current model were documented, particularly its complexity and slow response time. Several additional enhancements, such as security and history, are needed to maintain an accurate and confidential database. Plans still include the addition of all data currently loaded

as flat files to be incorporated into the improved model.

- The sea turtle system was designed and loaded into Oracle. Much time was spent analyzing the existing system that was not Y2K compliant and did not adhere to NMFS database management standards, resolving a problem of dropped records by the existing software. The data were cleaned that they could be entered into the database. Existing forms and reports were converted to both Microsoft Access and Oracle, and procedures were developed to move data between laptops and workstations using Microsoft Access and the UNIX host with Oracle RDBMS.

- An Oracle web server was set up and moved behind the firewall into the DMZ. It was successfully tested to provide immediate access to data stored in Oracle database via Developer 2000 modules. The capability to browse, query, select, and download data in standard ASCII format via both the Internet and our in-house Intranet depending on data confidentiality requirements was developed.

- GIS were designed and developed in support of several projects:

  Council contractor was provided reports from the SWR Longline/Turtle Observer data.

  The WPacFIN was provided with plots of drift tracks of survey assessment cruises conducted by the Guam fisheries office.

  Procedures were developed to move data from SAS to Arc View to provide statistical summaries of all *Townsend Cromwell* lobster data sets.

  FMPI personnel were provided with summary maps and overhead charts with CPUE statistics for most commercial species in the Hawaii longline fishery for 1998.

  The SWR and Council were provided with plots of American Samoa albacore fishing locations.

  A catalog of quality island outlines, bathymetry and exclusive economic zone data sets for use in Arc View and Arc Info was prepared.

  A metadata model for coverages and shapefiles was created or provided to the lab by outside agencies.

World Wide Web Sites

A great deal of time and effort has gone into the development of several world wide web sites now hosted by the Honolulu Laboratory. In addition to the General Laboratory web site, an Intranet web site, Coastwatch, WPacFIN web sites, and a *Townsend Cromwell* student connection web site, several investigations have developed their own sites which are linked into the Intranet. These sites provide instant information about the scientific studies and activities of the Honolulu Laboratory.

The Honolulu Laboratory Intranet web site is currently being redesigned and re-developed. Information and background research has been obtained to define user preferences, needs, and maintenance issues. A redesign includes a Honolulu Laboratory web site portal which gives immediate access to all of the Laboratory's web sites as well as other frequently used web sites of interest to Laboratory employees. The purpose of the intranet is to provide Laboratory employees ready access to detailed information about the various Laboratory service groups, team networks, data access and sharing, and online procedures and forms. The next steps are to re-evaluate user needs, establish new protocols for implementation, and further design and development.

The Honolulu Laboratory Internet Web Site has been developed and published on the world wide web (WWW). It contains introductory articles about the Laboratory, protected species research, fisheries research, fisheries data, the research investigations and the programs within them, Laboratory services, and the Director's Office. In addition, the web site includes a focus article to highlight specific issues of current interest, downloadable public brochures, information about the Honolulu Laboratory Renewal Project, our research partners, an organizational chart, a site map, and a search engine. Web access has been developed to a variety of fisheries data sets and reports such as GIS coverages, generating quarterly and annual reports on the fly from data stored in Oracle. The ability to query and download data stored in Oracle, as well as the ability to download files from the Honolulu Laboratory's FTP server has also been developed; the URL is **http://www.nmfs.hawaii.edu/**.

The Laboratory also hosts the NOAA Hawaii CoastWatch and Western Pacific Fisheries Information Network (WPacFIN) web sites. They provide access to high quality environmental data and state/territory fisheries of the Western Pacific information. Their URL's are **http://coastwatch.nmfs.hawaii.edu/** and **http://wpacfin.nmfs.hawaii.edu/,** respectively.

The Laboratory hosts the Townsend Cromwell Student Connection Web Site**.** The Laboratory has volunteered time and resources in cooperation with the NOAA Ship *Townsend Cromwell* to produce an outreach web site targeted at elementary and high school students as well as the general public. Our Web Master has worked with NOAA Corps Officers and Laboratory programmers to design, implement, and maintain this highly praised web site. Its purpose is to promote marine science to high school and other students, by bringing the study of the ocean into the classroom to inform students and teachers of current research and cooperative efforts. At this site, you can follow the day-to-day activities of the ship by reading diary type write-ups, view pictures, read up on previous cruise activities, access the cruise plan, post questions to the project manager, and read the questions and answers on a bulletin board. The URL is **http://atsea.nmfs.hawaii.edu.**

HONOLULU LABORATORY RENEWAL PROJECT (HLRP)

Background

The Honolulu Laboratory building is 50 years old and has become somewhat dilapidated, very much out of date in its scientific infrastructure, and overcrowded. NOAA is substantially the scoping and planning stages to determine what is the appropriate course of action for renewing the facility. The total cost of the project is estimated to be approximately $45 million. Recent accomplishments and deliverables are listed below.

Conceptual Design & Cost Estimate Final Report (June 1999)

The *Conceptual Design* provides a general outline of the two alternatives by incorporating NMFS Honolulu Laboratory, Pacific Islands Area Office, and Southwest Enforcement program requirements on the project site on Dole Street (Fig. 1). It also provides some detailed specification of construction requirements and provides a cost estimate.

The next critical stage in the design process is working out potential easements with the University of Hawaii and East-West Center concerning access to the Laboratory site from Dole Street and Pope Road.

Final Environmental Assessment Report (August 1999)

The Environmental Assessment outlines the potential impact of the project on the human and natural environment at the project site and suggests methods for mitigating those impacts.

The next critical steps in this will involve discussions with the University, East-West Center, and City & County of Honolulu on various identified issues requiring mitigation (e.g., traffic, noise, and construction scheduling).

NOAA Decision on Alternatives (Scheduled in Mid-August, 1999)

HLRP Program and Project Managers will brief NOAA and Department of Commerce management on the renewal alternatives to obtain authorization to proceed to the Design Phase (architectural and engineering drawings).

Procurement of A/E Design Contractor

The A/E Design Contractor is responsible for taking the reports from the planning and scoping phase of the project (primarily the Facilities Requirement Report and the Conceptual Design Report) and, in collaboration with NMFS Hawaii staff and NOAA, turning these concepts into the detailed specifications for the building. Twenty-three firms applied for the A/E design tasking; the list has been narrowed to three, with selection expected in September 1999.

Procurement of CM Contractor

The construction manager serves as an advisor to the owner of a project (in this case NOAA) to reduce costs and ensure quality control during the late design phase of the project and during construction. Seven firms applied for the CM task with selection expected later this year.

Construction is scheduled to begin around July 2001 and be completed by November 2002.

Temporary Relocation Space

The most critical current activity for Honolulu Laboratory staff is planning for the move to temporary quarters during the years of the construction phase of the project. Activities in the stage include selection of criteria for temporary space (e.g., proximity to the University, type of functions to be performed at the site, etc.), identification of space needs, site solicitation (by WASC and GSA), and preparation for the move. The anticipated date for this move is approximately June 2001. PIAO moved to temporary space in July 1999.

Figure 1. Artist's rendition of the new construction alternative for a replacement facility.

COMMUNITY OUTREACH

Background Information

The Community Outreach Program serves as the focus for the communication of scientific programs with outside agencies and the public. Special emphasis is given to the support of fisheries management and the recovery of the Hawaiian monk seal and Pacific sea turtle.

Goals and Objectives

The objective of the program is to seek and create opportunities to inform and educate the public of the Laboratory's mission and its impact on the economy and environment in the Pacific. This is accomplished by the following:

- Raising the awareness of the general public to gain support for the programs of the Honolulu Laboratory.
- Educating young people to instill an awareness of and responsibility for the environment.
- Establishing Honolulu Laboratory as a resource for the community by networking with community groups, schools, and other organizations.
- Promoting careers in ocean science.
- Developing with teachers age-appropriate curriculum that supports the objectives of the Honolulu Laboratory.

Major Activities

Presentations

Presentations are our most common outreach activity and as in years past the laboratory has accepted a number of invitations to make presentations to schools, universities, and interested groups. By the time the year is over, we will have delivered over 30 presentations with an emphasis on raising awareness and gaining support for protecting Hawaii's marine resources.

Participation

In an effort to establish the Honolulu Laboratory as a resource to the community, the Laboratory participated in community events such as the Fishermen's Festival, Waianae Ho'olaulea (Ahi Fever '99 fishing tournament), Hawaii State Science and Engineering Fair, and Opportunities in Science and Technology Mini-Expo. The laboratory also participated in a number of career fairs at schools to encourage students to choose careers in marine science.

This year, to highlight 50 years of science at the Honolulu Laboratory, a number of activities were hosted. Among them was a special session at the Tuna Conference featuring 50 years of tuna research at the Honolulu Laboratory. In addition, a commemorative session was held at the Eastern Pacific Oceanic Conference (EPOC) on the contributions made by the Laboratory to understanding the oceanography of the Pacific. In January, delegates from several countries attended the meeting of the Interim Scientific Committee for Tuna and Tuna-like Species in the North Pacific. In conjunction with the meeting, a reception for present and former staff and constituents was held to celebrate the Honolulu Laboratory's golden anniversary. In March, a press reception was held to announce plans for construction of a new facility and to celebrate the Laboratory's receipt of the prestigious Vice-Presidential Silver Hammer Award presented by Senator Daniel Inouye. Legislators from Federal, State, and City and County along with representatives from other agencies and the private sector were present as the Laboratory was recognized for its marine debris cleanup efforts.

Consultation

Throughout the year, the laboratory receives many requests and inquiries from teachers and other interested parties. Requests have resulted in the laboratory's providing information and material in the form of posters, brochures, and other teaching aids. On occasion, teachers have asked for advice or input regarding the appropriateness or correctness of material they already have. If we are not able to provide it, we often refer them to the appropriate agencies or resource people. Upon request, we have provided material--mainly photographs and specimens--to special groups for their own exhibit. The most recent has been for an exhibit entitled 'The History of the Japanese in Hawaii's Commercial Fishing Industry' at the Japanese Cultural Center of Hawaii. We provided NMFS publications, reports, data, statistics, and large photographs.

Development of Material

This year, the material we have available was assessed to determine whether it is current. In addition, we are in the process of developing age-appropriate outreach material such as bookmarks, short story books, coloring books, and handouts for use by schools, nonprofit organizations, and the general public with special emphasis on the recovery of the Hawaiian monk seal and the Pacific sea turtle. Also underway are plans to create a video for use by the hotel industry on its in-house television channels to educate the public about endangered species.

Promotion

The Laboratory will continue to take, as well as create, opportunities to promote the Honolulu Laboratory and its programs. Extensive work has been done on our laboratory website. The intranet is currently undergoing massive revisions to make it more user friendly for our internal customers. When completed, employees will be able to have access to a number of services and a wealth of information about the laboratory. In addition, we hope to use public interest in the internet to promote Honolulu Laboratory activities to the general public. Community outreach will have its own page dedicated to keeping the public informed of events the laboratory is sponsoring or participating in. The website will also be used to publicize the services the laboratory has to offer the community such as classroom visitations, career day speakers, teacher assistance, and written educational material.

The *Townsend Cromwell* web site, 'Student Connection,' has been marketed as an interactive tool for teachers to put their students in the field with research scientists aboard our research vessel *Townsend Cromwell*. Educating the young will continue to be a top priority as we recognize that instilling an awareness of and responsibility for the environment in our young people

will help ensure support for protecting Hawaii's marine resources in the future. We will continue to give presentations to schools and others to promote interest in careers in science. Plans for furthering community outreach in the new building are already in progress as we take advantage of the design process to identify space for displays, presentations, and visits.

APPENDIX A

HONOLULU LABORATORY PUBLICATIONS
(From October 1998 through September 1999)

Aguirre, A. A.

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Aguirre, A. A., C. J. Limpus, T. R. Spraker, and G. H. Balazs.

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Aguirre, A. A., T. R. Spraker, A. Chaves, L. du Toit, W. Eure, and G. H. Balazs.

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